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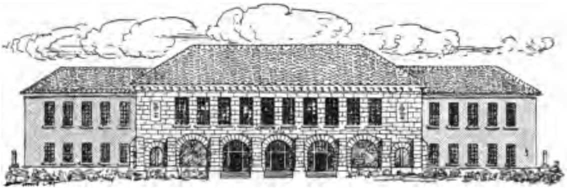

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BOTANY

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1. "From fragile mushrooms, delicate water-weeds and pond scums, to floating leaves, soft grasses, coarse weeds, tall bushes, slender climbers, gigantic trees, and hanging moss." See Chapter I.

BOTANY

ELEMENTARY TEXT
FOR SCHOOLS

BY

L. H. BAILEY

FOURTH EDITION

New York
THE MACMILLAN COMPANY
LONDON: MACMILLAN & CO., Ltd.
1904

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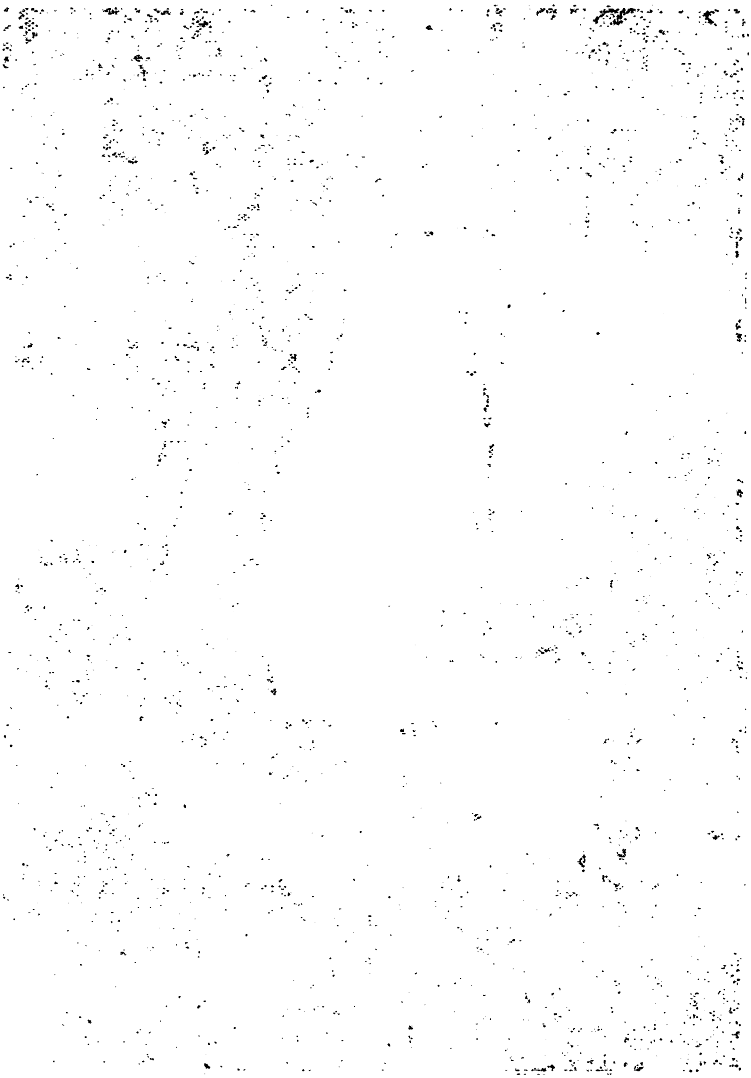

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AN ELEMENTARY TEXT FOR SCHOOLS

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PARAGRAPHS FOR THE TEACHER

(*Revised for second edition.*)

THIS book is made for the pupil: "Lessons with Plants" was made to supplement the work of the teacher.

There are four general subjects in this book: the nature of the plant itself; the relation of the plant to its surroundings; histological studies; determination of the kinds of plants. From the pedagogical point of view, the third is the least important: the writer has inserted it because so many schools want it. Each of the subjects is practically distinct, so that the teacher may begin where he will. Few schools will desire to pursue all the four parts

The notes in small type at the ends of the chapters are intended as suggestions and to supply information to teachers: they are not necessarily for class use. The explanation of karyokinesis, for example, on page 239, is intended to answer frequent inquiries from teachers; it is not to be taught to beginners. The main object of the "Notes," however, is to suggest experiments and corollary observations.

* * * * *

The schools and the teachers are not ready for the text-book which presents the subject from the view-point of botanical science. Perhaps it is better

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that the secondary schools attempt only to teach plants.

A book may be ideal from the specialist's point of view, and yet be of little use to the pupil and the school.

Every statement in an elementary text-book has two values,— the teaching value and the scientific value. An elementary text-book exists primarily for the purpose of teaching; and good teaching results in quickened perception rather than in absorption of facts.

The pupil should come to the study of plants and animals with little more than his natural and native powers. Study with the compound microscope is a specialization to be made when the pupil has had experience, and when his judgment and sense of relationships are trained.

One of the first things that a child should learn when he comes to the study of natural history is the fact that no two things are alike. This leads to an apprehension of the correlated fact that every animal and plant contends for an opportunity to live, and this is the central fact in the study of living things. The world has a new meaning when this fact is understood.

The ninety and nine cannot and should not be botanists, but everyone can love plants and nature. Every person is interested in the evident things, few in the abstruse and recondite. Education should train persons to live, rather than to be scientists.

Now and then a pupil develops a love of science for science's sake. He would be an investigator. He would add to the sum of human knowledge. He should be encouraged. There are colleges and universities in which he may continue his studies.

In the secondary schools botany should be taught for the purpose of bringing the pupil closer to the things with which he lives, of widening his horizon, of intensifying his hold on life. It should begin with familiar plant forms and phenomena. It should be related to the experiences of the daily life. It should not be taught for the purpose of making the pupil a specialist: that effort should be retained for the few who develop a taste for special knowledge. It is often said that the high-school pupil should begin the study of botany with the lowest and simplest forms of life. This is wrong. The microscope is not an introduction to nature. It is said that the physiology of plants can be best understood by beginning with the lower forms. This may be true: but technical plant physiology is not a subject for the beginner. Other subjects are more important.

The youth is by nature a generalist. He should not be forced to be a specialist.

* * * * *

A great difficulty in the teaching of botany is to determine what are the most profitable topics for consideration. The trouble with much of the teaching is that it attempts to go too far, and the subjects have no vital connection with the pupil's life.

Good botanical teaching for the young is replete with human interest. It is connected with the common associations.

The teacher often hesitates to teach botany because of lack of technical knowledge of the subject. This is well; but technical knowledge of the subject does not make a good teacher. Expert specialists are so likely to go into mere details and to pursue particular subjects so far, when teaching beginners, as to miss the leading and emphatic points. They are so cognizant of exceptions to every rule that they qualify their statements until the statements have no force. There are other ideals than those of mere accuracy. In other words, it is more important that the teacher be a good teacher than a good botanist. One may be so exact that his words mean nothing. But being a good botanist does not spoil a good teacher.

An imperfect method that is adapted to one's use is better than a perfect one that cannot be used. Some school laboratories are so perfect that they discourage the pupil in taking up investigations when thrown on his own resources. Imperfect equipment often encourages ingenuity and originality. A good teacher is better than all the laboratories and apparatus.

Good teaching devolves on the personality and enthusiasm of the teacher; but subject-matter is a prime requisite. The teacher should know more than he attempts to teach. Every teacher should have access to the current botanical books. The school library should contain these books. By consulting the new books the teacher keeps abreast of the latest opinion.

* * * * *

When beginning to teach plants, think more of the pupil than of botany. The pupil's mind and sympathies are to be expanded: the science of botany is not to be extended. The teacher who thinks first of his subject teaches science; he who thinks first of his pupil teaches nature-study.

Teach first the things nearest to hand. When the pupil has seen the common, he may be introduced to the rare and distant. We live in the midst of common things.

The old way of teaching botany was to teach the forms and the names of plants. It is now proposed that only function be taught. But one cannot study function intelligently without some knowledge of plant forms and names. He must know the language of the subject. The study of form and function should go together. Correlate what a plant is with what it does. What is this part? What is its office, or how did it come to be? It were a pity to teach phyllotaxy without teaching light-relation: it were an equal pity to teach light-relation without teaching phyllotaxy.

Four epochs can be traced in the teaching of elementary botany: (1) The effort to know the names of plants and to classify. This was the outgrowth of the earlier aspect of plant knowledge, when it was necessary to make an inventory of the things in the world. (2) The desire to know the formal names of the parts of plants. This was an outgrowth of the study of gross morphology. Botanies came to be dictionaries of technical terms. (3) The effort to develop the powers of independent investigation. This was largely a result of the German laboratory system, which developed the trained specialist investigator. It emphasized the value of the compound microscope and other apparatus. This method is of the greatest service to botanical science, but its introduction into the secondary schools is usually unfortunate. (4) The effort to know the plant as a complete organism living its own life in a natural way. In the beginning of this epoch we are now living.

There is a general protest against the teaching of "big names" to pupils; but the pupil does not object to technical terms if he acquires them when he learns the thing to which they belong, as he acquires other language. When a part is discovered the name becomes a necessity, and is not easily forgotten. He should be taught not to memorize the names. The "hard" words of to-day are the familiar words of to-morrow. There are no words in this book harder than chrysanthemum, thermometer, and hippopotamus.

The book should be a guide to the plant: the plant should be a guide to the book.

Plants should not be personified or endowed outright with motives; but figures of speech and parables may often be employed to teach a lesson or to drive home a point.

Excite the pupil's interest rather than his wonder.

The better the teacher, the less he will confine himself to the questions at the end of the lesson.

Botany always should be taught by the "laboratory method:" that is, the pupil should work out the subjects directly from the specimens themselves. It is easy, however, to carry the laboratory method too far. With beginners, it is rarely good teaching merely to set a young pupil a task, expecting him to work it out. The pupil needs suggestions, help, and the enthusiasm inspired by a good teacher.

Specimens mean more to the pupil when he collects them.

No matter how commonplace the subject, a specimen will vivify it and fix it in the pupil's mind.

A living, growing plant is worth a score of herbarium specimens.

Acknowledgements.—To hundreds of young people in many places the author is under the profoundest obligations, for they have instructed him in the point of view. Specific aid has been given by many persons. From the teacher's point of view, proofs have been read by Miss Julia E. Rogers, Minburn, Iowa; Miss

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L. H. BAILEY.

HORTICULTURAL DEPARTMENT,
CORNELL UNIVERSITY, ITHACA, N. Y.
October 1, 1900.

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BOTANY

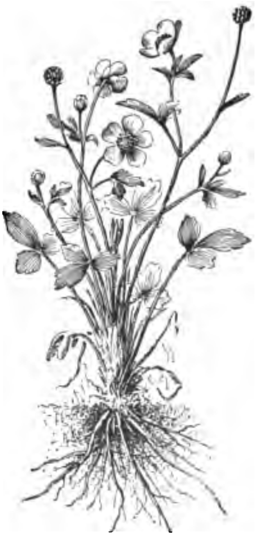
PART I — THE PLANT ITSELF

CHAPTER I

THE PLANT AS A WHOLE

1. **A plant is a living, growing thing.** It partakes of the soil and air and sunshine. It propagates its kind and covers the face of the earth. It has much with which to contend. It makes the most of every opportunity. We shall learn its parts, how it lives, and how it behaves.

2. **THE PARTS OF A PLANT.** — Our familiar plants are made up of several distinct parts. The most prominent of these parts are **root, stem, leaf, flower, fruit and seed.** Fig. 2. *Familiar plants differ wonderfully in size and shape*,— from fragile mushrooms, delicate water-weeds and pond-scums, to floating leaves, soft grasses, coarse weeds, tall bushes, slender climbers, gigantic trees, and hanging moss. See frontispiece.



2. A buttercup plant, showing the various parts.

3. **THE STEM PART.**—In most plants there is a *main central part or shaft* on which the other or *secondary parts* are

borne. This main part is the **plant axis.** Above ground, in familiar plants, the axis bears the **branches, leaves and flowers**; below ground, it bears the **roots.**

4. The rigid part of the plant, which persists over winter and which is left after leaves and flowers are fallen, is the **framework of the plant.** The framework is composed of both root and stem. When the plant is dead, the framework remains for a time, but it slowly decays. The dry winter stems of weeds are the framework or skeleton of the plant. Figs. 3 and 4. The framework of trees is the most conspicuous part of the plant.

5. **THE ROOT PART.**—The root bears the stem at its apex, but otherwise it normally **bears only root-branches.** The stem, however, **bears leaves, flowers and fruits.** Those living surfaces of the plant which are most exposed to light are *green or highly colored.* The root tends to grow *downward*, but the stem tends to grow *upward toward light and air.* The plant is anchored or fixed in the soil by the roots. Plants have been called "earth parasites."

6. **THE FOLIAGE PART.**—The *leaves precede the flowers* in point of time or in the life of the plant. *The flowers always precede the fruits and seeds.* Many plants die when the seeds have matured. The whole mass of leaves of any plant or any branch is known as its **foliage.**

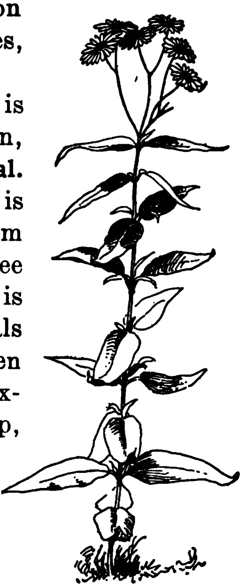
7. **THE PLANT GENERATION.**—The course of a plant's life, with all the events through which the plant naturally passes, is known as the plant's **life-history.** The life-history embraces various stages or epochs, as *dormant seed*, *germination*, *growth*, *flowering*, *fruiting.* Some plants run their course in a few weeks or months, and some live for centuries.

8. The entire life-period of a plant is called **a generation.** It is the whole period from birth to normal death, without reference to the various stages or events through which it passes.

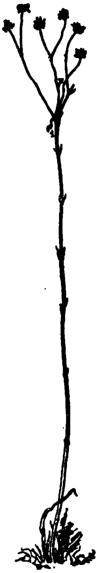
9. A generation begins with ***the young seed***, not with germination. *It ends with death* — that is, when no life is left in any part of the plant, and only the seed or spore remains to perpetuate the kind. In a bulbous plant, as a lily or an onion, the generation does not end until the bulb dies, even though the top is dead.

10. When the generation is of only one season's duration, the plant is said to be **annual.** When it is of two seasons, it is **biennial.** Biennials usually bloom the second year. When of three or more seasons, the plant is **perennial.** Examples of annuals are pigweed, bean, pea, garden sunflower; of biennials, foxglove, mullein, teasel, parsnip, carrot; of perennials, dock, meadow grass, cat-tail, and all shrubs and trees.

11. **DURATION OF THE PLANT BODY.** — Plant structures which are more or less soft and which die at the close of the season are said to be **herbaceous,** in contradistinction to being **ligneous** or **woody.** A plant which is herbaceous to the ground is called an **herb**; but an herb may have a woody or perennial root, in which case it is called an **herbaceous perennial.** Annual plants are classed as herbs. Examples of herbaceous perennials are buttercup (Fig. 2), bleeding heart, violet, water-lily, many grasses, dock, dandelion, golden rod, asparagus, rhubarb, many wild sunflowers (Figs. 3, 4).



3. Plant of a wild sunflower.



4. Framework of No. 3.

12. Many herbaceous perennials have ***short generations.***

They become weak with one or two seasons of flowering and gradually die out. Thus red clover begins to fail after the second year. Gardeners know that the best bloom of hollyhock, larkspur, pink, and many other plants, is secured when the plants are only two or three years old.

13. Herbaceous perennials which die away each season to bulbs or tubers, are sometimes called **pseud-annuals** (that is, false annuals). Of such are lily, crocus, onion, potato.

5. A shrub or bush. Dogwood osier.

14. Plants which are normally perennial **may become annual** *in a shorter-season climate by being killed by frost*, rather than by dying naturally at the end of a season of growth. Such plants are called **plur-annuals** in the short-season region. Many tropical perennials are plur-annuals when grown in the north, but they are treated as true annuals because they ripen sufficient of their crop the same season in which the seeds are sown to make them worth cultivating, as tomato, red pepper, castor bean.

15. Woody or ligneous plants are usually longer lived than herbs. Those which remain low and produce several or many similar shoots from the base are called **shrubs,** as lilac, rose, elder, osier. Fig. 5. Low and thick shrubs are **bushes.** Plants which produce one main trunk and a more or less elevated head are **trees.** Fig. 6.

16. **PLANTS ARE MODIFIED BY THE CONDITIONS IN WHICH THEY GROW.**—In most plants, the size, form and general appearance vary or change with the *conditions in which the plant grows.* That is, there is no uniform or necessary form into which plants shall grow. **No two plants are exactly alike.** Observe plants of the same kind and age, and see how they differ or vary. The farmer and gardener can cause plants to be large or small of their kind, by changing the conditions or circumstances under which they grow.

17. **No two parts of the same plant are exactly alike.** No two parts grow in the same conditions, for one is nearer the main stem, one nearer the light, and another has more room. Try to find two leaves or two branches on the same plant which are exactly alike. Fig. 7.

6. A tree. The weeping birch.

18. Every plant makes an effort *to propagate or to perpetuate its kind;* and as far as we can see, this is the end for which the plant itself lives. **The seed or spore is the final product of the plant.**

19. Every plant,—and every part of a plant,—undergoes vicissitudes. It has to **adapt itself to the conditions in which it lives.** It contends for place in which to

grow, and for air and light. Its life is eventful. ***Every plant, therefore, has a history and a story to tell.***

7. There are no two branches alike.

Review. — Of what parts is a plant composed? What is the axis? What parts are borne on the stem? On the root? On what part are the most highly colored parts found? What direction does the root take? The stem? How are plants anchored in the soil? In what order do the different parts appear? What is meant by the life-history? What are some of the stages or events in the life-history? At what point does a generation begin? When end? By what means does the next generation begin? What is an Annual? Biennial? Perennial? Herbaceous perennial? Pseud-annual? Shrub? Bush? Tree? Give three examples of each of these classes, not mentioning any given in the book. What is a plur-annual? Why are no two parts or plants exactly alike? What is the final effort of every plant? Why is the life of a plant eventful?

Note.—The teacher may assign each pupil to one plant in the school yard, field, or in a pot, and ask him to bring out the points in the lesson.

Winter-time brings out the framework of the plants.

CHAPTER II

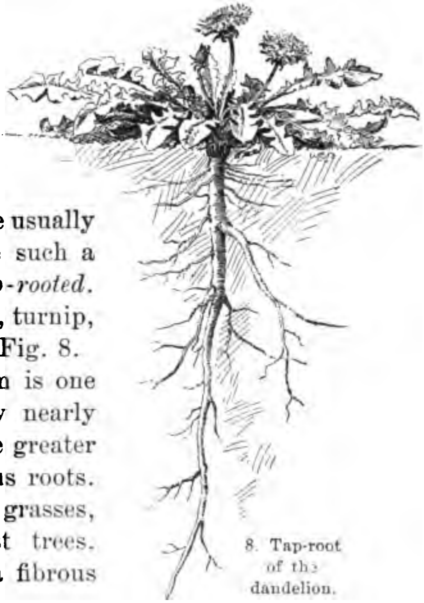
THE ROOT

20. **THE ROOT SYSTEM.**—The offices of the root are *to hold the plant in place, and to gather food.* Not all the food materials, however, are gathered by the roots.

21. The entire mass of roots of any plant is called its **root system.** The root system may be annual, biennial or perennial, herbaceous or woody, deep or shallow, large or small.

22. **KINDS OF ROOTS.**—A strong leading central root, which runs directly downwards, is a **tap-root.** The side or spreading roots are usually smaller. Plants which have such a root system are said to be *tap-rooted.* Examples are red clover, beet, turnip, radish, burdock, dandelion. Fig. 8.

23. A **fibrous root** system is one which is composed of many nearly equal slender branches. The greater number of plants have fibrous roots. Examples are many common grasses, wheat, oats, corn, and most trees. The buttercup in Fig. 2 has a fibrous root system.



8. Tap-root of the dandelion.

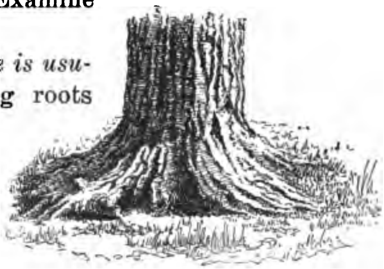
24. **SHAPE AND EXTENT OF THE ROOT SYSTEM.** — The depth to which roots extend depends on the **kind of plant, and the nature of the soil.** Of most plants the roots

9. The crooked roots exposed where the soil has been washed away.

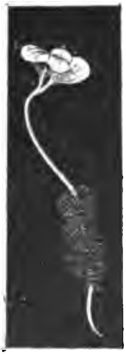
extend far *in all directions* and lie comparatively *near the surface.* The roots usually radiate from a common point just beneath the surface of the ground.

25. *The roots go here and there* **in search of food,** often extending much farther in all directions than the spread of the top of the plant. Roots tend to spread farther in poor soil than in rich soil. *The root has no such definite form as the stem has.* Roots are usually very crooked, because they are constantly turned aside by obstacles. Fig. 9. Examine roots in stony or gravelly soil.

26. *The extent of root surface is usually very large*, for the feeding roots are fine and very numerous. An ordinary plant of Indian corn may have a total length of root (measured as if the roots were placed end to end) of several hundred feet.



10. The bracing buttresses of a field pine.



11. Root-hairs of the radish.

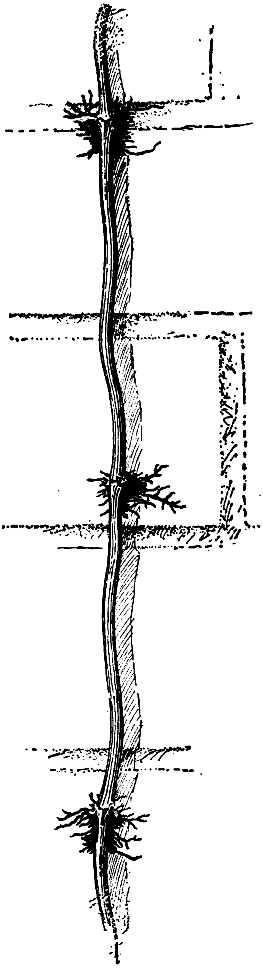
27. The fine feeding roots are **most abundant in the richest soil.** They are attracted by the food materials. Roots often will completely surround a bone or other morsel. When roots of trees are exposed, observe that most of

them are horizontal and lie near the top of the ground. Some roots, as of willows, go far *in search of water.* They often run into wells and drains, and into the margins of creeks and ponds. Grow plants in a long narrow box, in one end of which the soil is kept very dry and in the other moist: observe where the roots grow.

28. The feeding surface of the roots is **near their ends.** As the roots become old and hard, they serve only as *channels through which food passes* and as *hold-fasts or supports* for the plant. The root-hold of a plant is very strong. Slowly pull upwards on some plant, and note how firmly it is anchored in the soil. With the increase in diameter, the upper roots often protrude above the ground and become *bracing buttresses.* These buttresses are usually largest in trees which always have been exposed to strong winds. Fig. 10.

29. **THE ROOT-HAIRS.**—The larger part of the nourishment gathered by the root is taken in through **root-hairs.** Fig. 11. These are very *delicate prolonged surface cells of the roots.* They are borne for a short distance just back of the tip of the root.

30. The root-hairs are very small, often invisible. They, and the young roots, are usually broken off when the plant is pulled up. They are best seen when seeds are germinated between layers of dark blotting paper or flannel. On the young roots, they will be seen as a mould-like or gossamer-like covering. **Root-**

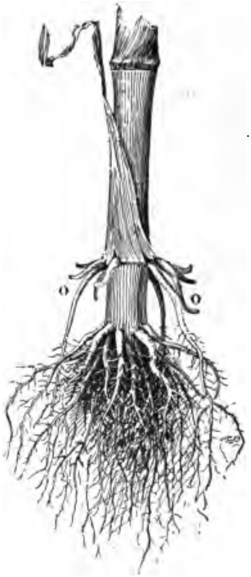


12. Aërial roots of trumpet creeper or tecoma.

hairs soon die: they do not grow into roots. New ones form as the root grows.

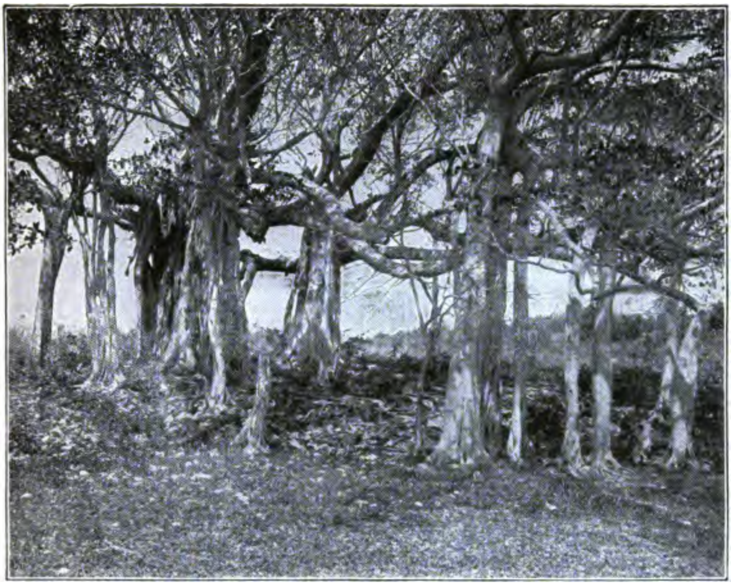
31. **AËRIAL ROOTS.**—Although most roots bury themselves in the soil, *there are some which grow above ground.* These usually occur on climbing plants, the roots becoming **supports** or fulfilling the office of tendrils. These aërial roots *usually turn away from the light*, and therefore enter the crevices and dark places of the wall or tree over which the plant climbs. The trumpet creeper (Fig. 12), true or English ivy, and poison ivy, climb by means of roots.

13. Aërial roots of an orchid.

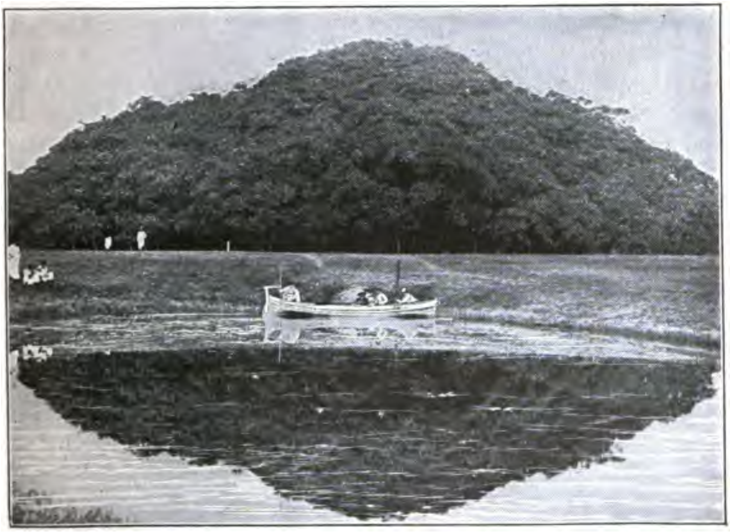


14. Indian corn, showing the aërial roots at *oo*.

32. In some plants, all the roots are aërial; that is, *the plant grows above ground*, and the roots gather food from the air. Such plants usually grow on trees. They are



15. A banyan tree in India. The old trunk is seen (at the left), together with many trunks formed from the aërial roots.



16. Banyan tree covering several acres. India.

known as *epiphytes* or *air-plants* (Chapter XIII). The most familiar examples are some of the tropical orchids, which are grown in glasshouses. Fig. 13.

33. Some plants throw out aërial roots, which *propagate the plant or act as braces.* The roots of Indian corn are familiar. Fig. 14. Many ficus trees, as the banyan of India (Figs. 15, 16), send out roots from their branches; when these roots reach the ground they take hold and become great trunks, thus spreading the top of the parent tree over great areas. The mangrove tree (Fig. 17) of the tropics grows along seashores and sends down roots from the overhanging branches into the shallow water, and thereby gradually marches into the sea. The tangled mass behind catches the drift, and soil is formed.

17. Mangroves marching into the sea.

REVIEW.—What is the root for? What is a root system? Define tap-root. Fibrous root. What determines how deep the root may go? How far does the root spread? Explain what form the root systom may assume; also what extent. Where are the greatest number of fine roots found? Where is the feeding surface of roots? Of what use to the plant are the old woody roots? What are root-hairs? What do they do and what becomes of them? What are aërial roots? Where found? What are epiphytes, and where do their roots grow? What are brace roots? How do the banyan and mangrove spread (aside from seeds)?

NOTE.—The pupil should see the root-hairs. A week before this lesson is studied, have the pupil place seeds of radish, turnip or cabbage between folds of thick cloth or blotting paper. Keep the cloth or paper moist and warm. The hairs show best against a dark background. In some of the blotting papers, sprinkle sand : observe how the root-hairs cling to the grains (compare Chapter XI).

The pupil also should study the root-hold of a plant. Let him carefully pull up a plant. If a plant grow alongside a fence or other rigid object, he may test the root-hold by securing a string to the plant, letting the string hang over the fence and then adding weights to the string. Will a stake of similar size to the plant and extending no deeper in the ground, have such firm hold on the soil ?

Garden along the school-yard fence, where pupils may grow the plants for study

CHAPTER III

THE STEM

34. **THE STEM SYSTEM.**—The stem of a plant is the part which *bears the buds, leaves, flowers and fruits.* Its office is **to hold these parts up to the light and air**; and through its tissues the various food-materials and the life-giving fluids are distributed to the growing and working parts.

18. Stem system of an apple tree. Deliquescent trunk.

35. The entire mass or fabric of stems of any plant is called **its stem system.** Figs. 4, 18. The stem system may be herbaceous or woody, annual, biennial, or perennial; and it may assume many different sizes and shapes.

36. *Stems are of many forms.* The general way in which a plant grows is called its **habit.** The habit is the *appearance or looks.* Its habit may be open or loose, dense, straight, crooked, compact, straggling, climbing, erect, weak, strong, and the like. The roots and leaves are **the important functional or working parts**: the stem merely connects them, and its form is exceedingly variable.

37. **KINDS OF STEMS.**—*The stem may be so short as to be scarcely distinguishable.* In such cases the crown of the plant—that part just at the surface of the ground—bears the leaves and flowers; but this crown is really a very short stem. The dandelion, Fig. 8, is an example. Such plants

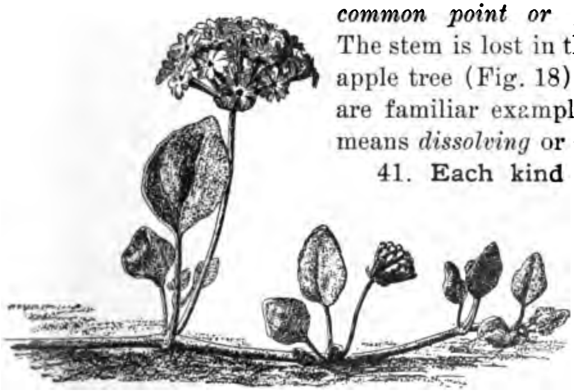
are often said to be **stemless**, however, in order to distinguish them from plants which have long or conspicuous stems. *These so-called stemless plants die to the ground every year.*

38. Stems are **erect** when they grow straight up. Figs. 1, 2, 3. They are **trailing** or **creeping** when they run along on the ground. Fig. 19. They are **decumbent** when they lop over to the ground. They are **ascending** when they lie mostly or in part on the ground but stand more or less upright at their ends. They are **climbing** when they cling to other objects for support. Figs. 12, 20.

39. Trees in which the main trunk or the "leader" continues to grow from its tip are said to be **excurrent** in growth. *The branches are borne along the sides of the trunk*, as in common pines (Fig. 21) and spruces. Excurrent means *running out* or *running up*.

40. Trees in which the main trunk does not continue are said to be **deliquescent.** *The branches arise from one common point or from each other.* The stem is lost in the branches. The apple tree (Fig. 18), maple, elm, oak, are familiar examples. Deliquescent means *dissolving* or *melting away*.

41. Each kind **of plant has its own peculiar habit or direction of growth.** Spruces always grow to a single stem or trunk, pear trees are always deliquescent, morning-glories are always climbing, strawberries are always creeping. We do not know why each plant has its own habit; but the habit is in some way *asso-*



19. A trailing plant (Abronia).

ciated with the plant's genealogy or with the way in which it has been obliged to live.

42. The stem may be **simple** or **branched.** A simple stem usually grows from the terminal bud, and side branches either do not start, or, if they start, they soon perish. Mulleins (Fig. 22) are usually simple. So are palms.

43. *Branched stems may be of very different habit and shape.* Some stem systems are narrow and erect: these are said to be *strict.* Others are *diffuse*, *open*, *branchy*, *twiggy*.

44. **STEMS vs. ROOTS.** — Roots sometimes grow above ground (31–33); so, also, *stems sometimes grow underground*, and they are then known as **subterranean stems, rhizomes,** or **rootstocks** (Fig. 23).

20. Grape vine climbing on a tree. Illustrating two kinds of stems.

45. **Stems normally bear leaves and buds, and thereby are they distinguished from roots.** The leaves, however, may be reduced to mere scales, and the buds beneath them may be scarcely visible. Thus the "eyes" on an Irish potato are cavities with a bud or buds at the bottom (Fig. 24). Sweet potatoes have no evident "eyes" when first dug (but they may develop buds before the next growing-

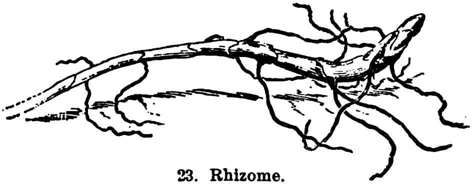
season). The Irish potato is a stem: the sweet potato is probably a root.

46. **HOW STEMS ELONGATE.**—*Roots elongate by* **growing near the tip.** *Stems elongate by* **growing more or less throughout the young or soft part** or "between joints." But any part of the stem soon reaches a limit beyond which it cannot grow, or becomes "fixed;" and the new parts beyond elongate until they, too, become rigid. When a part of the stem once becomes fixed or hard, it never increases in length: that is, *the trunk or woody parts never grow longer or higher; branches do not become farther apart or higher from the ground.*

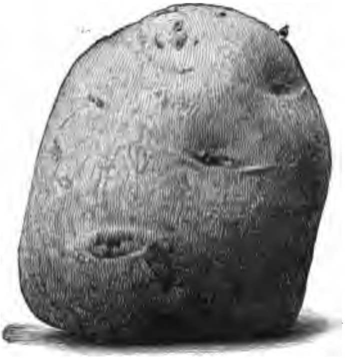
22. Old mullein stalk, with strict habit of growth.

21. Excurrent trunk. A pine.

47. The different regions of growth in stems and roots may be observed in seedling plants. Place seeds of radish or cabbage between layers of blotting-paper or thick cloth. Keep them damp and warm. When stem and root have grown an inch and a half long each, with waterproof ink mark spaces exactly one-quarter inch apart. Keep the plantlets moist for a day or two, and it will be found that on the stem some or all of the marks are more than one-quarter inch apart; on the root the marks have not separated. The root has grown beyond the last mark. Figs. 25 and 26.



23. Rhizome.

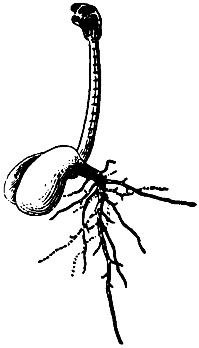


24. A thickened stem, bearing buds or "eyes."—Potato.

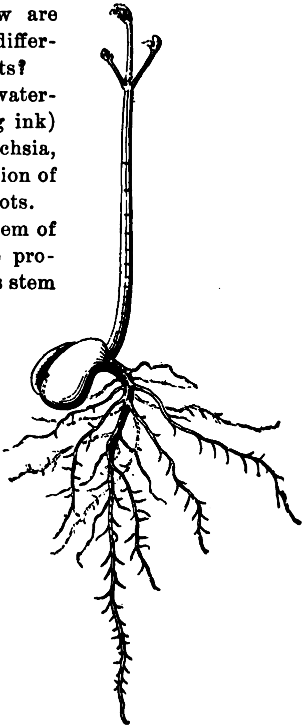
Review. — What is the stem system? What does the stem do? How long may the stem persist? What is meant by the habit of a plant? Name some kinds of habit. What are so-called stemless plants? What is the crown? What becomes of the tops of stemless plants? What are erect, trailing, decumbent, ascending, climbing stems? What are excurrent trunks? Deliquescent? What is a simple stem? What are strict stems? What are subterranean stems? How are stems distinguished from roots? What is the difference in mode of growth between stems and roots?

Note.—The pupil should make marks with waterproof ink (as Higgins' ink or indelible marking ink) on any soft growing stems—as geranium, fuchsia, grass, the twigs of trees. Note that the separation of the marks is most evident on the youngest shoots.

The pupil should observe the fact that a stem of a plant has wonderful strength. Compare the proportionate height, diameter and weight of a grass stem with those of the slenderest tower or steeple. Which has the greater strength? Which the greater height? Which will withstand the most wind? Note that the grass stem will regain its position even if its top is bent to the ground. Split a corn stalk and observe how the joints are tied together and braced with fibers. Note how plants are weighted down after a heavy rain.



25. The marking of the stem and root.



26. The result.

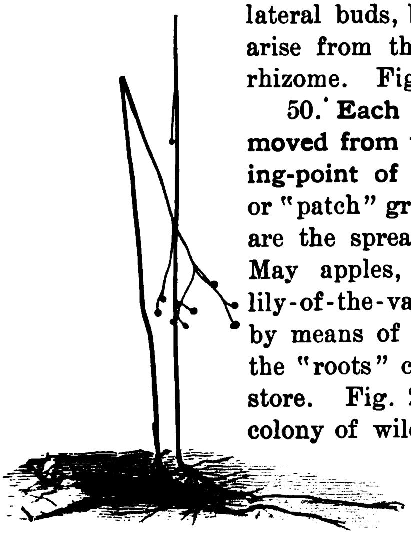
CHAPTER IV

PROPAGATION BY MEANS OF ROOTS AND STEMS

48. The primary office of roots and stems is to support and maintain the plant; *but these parts may also serve to propagate the plant*, **or to produce new individuals.**

49. **PROPAGATION BY MEANS OF RHIZOMES.**— *One office of subterranean stems or rhizomes is to propagate the plant.* Each stem has **a bud at its end**, and from this bud a shoot arises. By the dying away of the older part of the rhizome, this shoot becomes a separate plant, although the rhizome maintains its connection for years in some plants. Shoots may also arise from the intermediate or lateral buds, but the strongest shoots usually arise from the end or near the end of the rhizome. Fig. 23.

50. **Each successive plant is farther removed from the original plant or the starting-point of the colony.** Thus the colony or "patch" grows larger. Familiar examples are the spreading patches of mandrakes or May apples, quack-grass, Solomon's seal, lily-of-the-valley, ferns. Cannas propagate by means of rhizomes; so does ginger, and the "roots" can be purchased at the drug store. Fig. 27 illustrates the spread of a colony of wild sunflower. On the right the rhizomes have died away: note the frayed ends. On the left, the strong up-turned buds show where the shoots



27. Creeping rhizomes of wild sunflower.

will arise next spring. The old stems in the middle show where the buds were at the close of the last season. Fig. 23 shows one of the terminal buds.

51. *When rhizomes are cut in pieces, each piece having at least one bud or "eye," the pieces may grow when planted.* A familiar example is the practice of dividing tubers of potato. A severed piece of plant designed to be used to propagate the plant is a **cutting.** See Fig. 28.

28. Cuttings of canna rhizome.

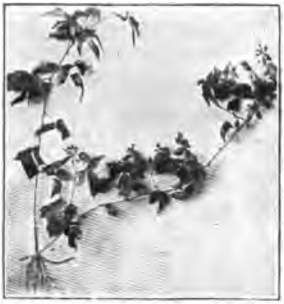
52. *Cuttings of rhizomes are often made undesignedly or accidentally when land is cultivated.* The cultivator or harrow breaks up the rhizomes of quack-grass, Canada thistle, toad flax, and other weeds, and scatters them over the field.

53. **PROPAGATION BY MEANS OF ROOTS.—Roots sometimes make buds** *and throw up shoots or new plants.* Severed roots, or root cuttings, often grow. Blackberries, raspberries, and many plums and cherries, throw up shoots or "suckers" from the roots; and this propensity is usu-

ally increased when the roots are broken, as by a plow. Broken roots of apples often sprout. Plants may propagate by means of **root cuttings.**

54. The buds which appear on roots are unusual or abnormal,—they occur only occasionally and in no definite order. Buds appearing in unusual places on any part of the plant are called **adventitious buds.** Such are the buds which arise when a large limb is cut off, and from which suckers or watersprouts arise.

55. **LAYERS.**—*Roots sometimes arise from aërial stems that are partially buried.* If a branch touches the ground and takes root, it is called a **layer.** Gardeners often bend a limb to the ground and cover it for a short distance, and when roots have formed on the covered part, the branch is severed from its parent and an independent plant is obtained. See Fig. 29.



29. A layer of dewberry. The new plant has arisen at the left.

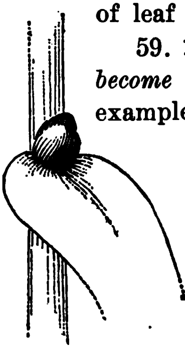
56. There are several kinds of layers: a **creeper,** when a trailing shoot takes root throughout its entire length; a **runner,** when the shoot trails on the ground and takes root at the joints, as the strawberry; a **stolon,** when a more or less strong shoot bends over and takes root, as the black raspberry or the dewberry (Fig. 29); an **offset,** when a few very strong plants form close about the base of the parent, particularly in succulent or bulbous plants, as house-leek (old-hen-and-chickens) and some lilies. The rooting branches of the mangrove and banyan (Figs. 15, 17) may be likened to layers.

57. **NATURAL CUTTINGS.** — *Sometimes cuttings occur* **without the aid of man.** Some kinds of willows shed

their twigs, or the storms break them off: many of these twigs take root in the moist earth where willows grow, and they are often carried down the streams and are washed along the shores of lakes. Observe the willows along a brook, and determine whether any of them may have come down the stream.

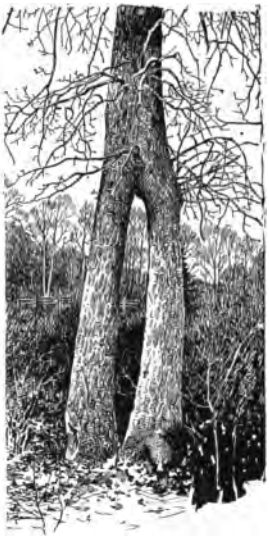
58. **PROPAGATION BY MEANS OF LEAVES.—Even leaves may take root** *and give rise to new plants.* There are examples in warm countries. The lake-cress of northern streams also propagates in this way: the leaves with little plants attached may often be seen floating down stream. Gardeners propagate some kinds of begonias by means of leaf cuttings; also gloxinias and bryophyllums.

59. **PROPAGATION BY MEANS OF BUDS.**—*Buds often become detached and propagate the plant.* Familiar examples are the bulblets of tiger lilies, borne amongst the foliage; for all bulblets and bulbs are only special kinds of buds. Fig. 30. Some water plants make heavy winter buds, which become detached on the approach of cold weather and sink to the bottom. In spring, they give rise to new plants.

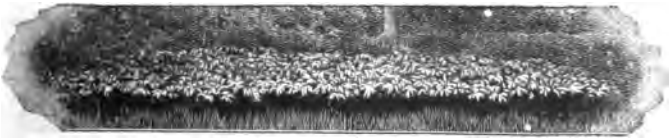

30. Bulblet of tiger lily.

60. **GRAFTS.** — *Sometimes a branch may unite with another plant.* A branch or a trunk may lie against another plant of the same kind, or of a very closely related kind, and grow fast to it; and if its original trunk die away, the part will be growing on an alien root. *A branch which grows fast to a branch of another plant, the wood of the two knitting together, is called* **a graft.** Fig. 31. It is necessary to distinguish between a graft and a parasite: a parasite preys upon another plant, robbing it of its food, but a graft becomes an integral part of the stock on which it grows, and does its full work in elaborating food for itself and for the stock.

REVIEW.—What are primary and secondary offices of roots and stems? What are the offices of rhizomes? How does propagation by rhizomes proceed? Why does the colony spread? Name some plants which propagate by means of rhizomes. What is a cutting? May cuttings be made of rhizomes? How are rhizomatous weeds often spread? How do roots serve to propagate the plant? Name instances. What are adventitious buds? What is a layer? Define some of the kinds of layers,—runner, creeper, stolon, offset. Explain how cuttings may occur without the aid of man. How may leaves serve to propagate the plant? Explain how plants propagate themselves by means of detachable buds. What is a graft? How may grafting take place without the aid of man?


31. A native graft.

NOTE.—If there is an accessible "patch" of toad-flax, Canada thistle, May apple, or other perennial plant, the pupil should determine by what means it enlarges from year to year. "Patches" are always instructive when considered with reference to propagation and dissemination.


A patch or colony of May apple.

CHAPTER V

HOW THE HORTICULTURIST PROPAGATES PLANTS BY MEANS OF ROOTS AND STEMS

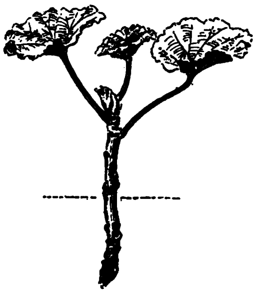
61. **CUTTINGS IN GENERAL.**—*A bit of a plant stuck into the ground stands a chance of growing; and this bit is a* **cutting.** (Compare 51.) Plants have preferences, however, as to the kind of a bit which shall be used, but *there is no way of telling what this preference is except by trying.* In some instances this preference has not been discovered, and we say that the plant cannot be propagated by cuttings.

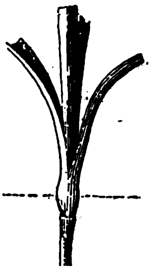
62. Most plants prefer that the cutting be made of the **soft** or **growing parts** (called "wood" by gardeners), of which the "slips" of geranium and coleus are examples. Others grow equally well from cuttings of the **hard** or **mature parts** or **wood,** as currant and grape; and in some instances this mature wood may be of roots, as in the blackberry. Pupils should make cuttings now and then. If they can do nothing more, they can make cuttings of potato, as the farmer does; and they can plant them in a box in the window.

63. **THE SOFTWOOD CUTTING.**—The softwood cutting is made from tissue which is still growing, or at least from that which is not dormant. *It comprises one or two joints, with a leaf attached.* Figs. 32, 33, 34. It must not be allowed to wilt. Therefore, it must be **protected from direct sunlight and dry air** *until it is well established; and if it has many leaves, some of them should be removed, or at least cut in two, in order to reduce the evaporating surface.* The soil should be uni-

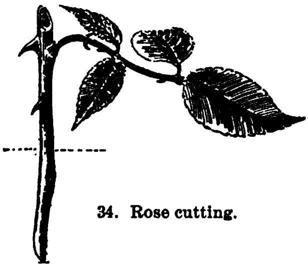
formly moist. The pictures show the depth to which the cuttings are planted.

64. For most plants, the proper age or maturity of wood for the making of cuttings may be determined by giving the *twig a quick bend: if it snaps and hangs by the bark, it is in proper condition; if it bends without breaking, it is too young and soft or too old; if it splinters, it is too old and woody*. The tips of strong upright shoots usually make the best cuttings. Preferably, each cutting should have a joint or node near its base; and if the internodes (or spaces between joints) are very short, it may comprise two or three joints.


32. Geranium cutting.

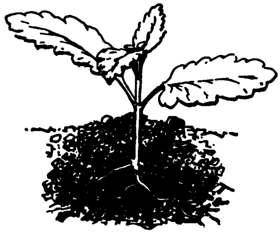

33. Carnation cutting.

65. *The stem of the cutting is inserted one-third or more its length in clean sand or gravel, and the earth is pressed firmly about it.* A newspaper may be laid over the bed to exclude the light—if the sun strikes it—and to prevent too rapid evaporation. The soil should be moist clear through, not on top only.


34. Rose cutting.

66. *Loose sandy or gravelly soil is used.* Mason's sand is good earth in which to start most cuttings; or fine gravel—sifted of most of its earthy matter—may be used. Soils are avoided which contain much decaying organic matter, for these soils are breeding places of fungi, which attack the soft cutting and cause it to "damp off," or to die at or near the

surface of the ground. If the cuttings are to be grown in a window, put three or four inches of the earth in a shallow box or a pan. A soap box cut in two lengthwise, so that it makes a box four or five inches deep — like a gardener's flat—is excellent. Cuttings of common plants, as geranium, coleus, fuchsia, carnation, are kept at a living-room temperature. As long as the cuttings look bright and green, they are in good condition. It may be a month before roots form. When roots have formed, the plants begin to make new leaves at the tip. Then they may be transplanted into other boxes or into pots. The verbena in Fig. 35 is just ready for transplanting.


35. Verbena cutting ready for transplanting

67. It is not always easy to find growing shoots from which to make the cuttings. The best practice, in that case, is **to cut back an old plant,** *then keep it warm and well watered, and thereby force it to throw out new shoots.* The old geranium plant from the window-garden, or the one taken up from the lawn bed, may be treated this way. See Fig. 36. The best plants of geranium and coleus and most window plants are those which are not more than one year old. *The geranium and fuchsia cuttings which are made in January, Febru-*

36. Old geranium plant cut back to make it throw out shoots from which cuttings can be made.

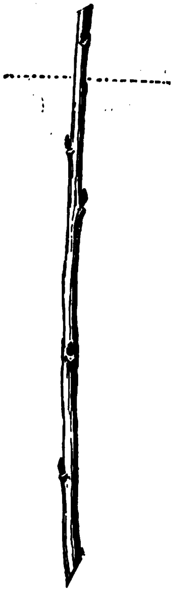
ary, or March will give compact blooming plants for the next winter; and thereafter new ones take their places. Fig. 37.

68. **THE HARDWOOD CUTTING.**—*Best results are secured when the cuttings are made in the fall and then buried until spring in sand in the cellar.* These cuttings are usually 6 to 10 inches long. They are not idle while they rest. The lower end calluses or heals, and the roots form more readily when the cutting is planted in the spring. But if the proper season has passed, take cuttings at any time in winter, plant them in a deep box in the window, and watch. They will need no shading or special care. Grape, currant, gooseberry and poplar readily take root from the hardwood. Fig. 38 shows a currant cutting. It has only one bud above the ground.

37. Early winter geranium, from a spring cutting.

69. **THE GRAFT.**—*When the cutting is inserted in a plant rather than in the soil, we have a graft;* and the graft may grow. In this case the cutting grows fast to the other plant, and the two become one. When the cutting is inserted in a plant, it is no longer called a cutting, but a **cion**; and the plant in which it is inserted is called the **stock**. Fruit trees are grafted *in order that a certain variety or kind may be perpetuated.*

70. *Plants have preferences as to the stocks on which they will grow; but we can find out what their choice is* **only by making the experiment.** The pear grows well on the quince, but the quince does not grow so well on the pear. The pear grows on some of the hawthorns, but it is an unwilling subject on the apple. Tomato plants will grow on potato plants and potato plants on tomato plants. When the potato is the root, both tomatoes and potatoes may be produced; when the tomato is the root, neither potatoes nor tomatoes will be produced. Chestnut will grow on some kinds of oak.


38. Currant cutting.

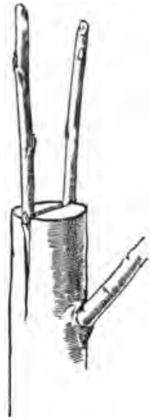
71. *The forming, growing tissue of the stem* (on the plants we have been discussing) *is the* **cambium,** *lying on the outside of the woody cylinder, beneath the bark.* In order that union may take place, **the cambium of the cion and of the stock must come together.** Therefore the cion is set in the side of the stock. There are many ways of shaping the cion and of preparing the stock to receive it. These ways are dictated largely by the relative sizes of cion and stock, although many of them are matters of mere personal preference. The underlying principles are two: securing **close contact** between the cambiums of cion and stock; **covering the wounded surfaces** to prevent evaporation and to protect the parts from disease.

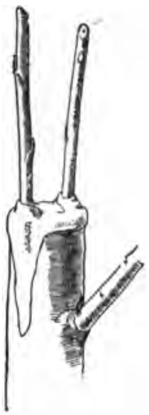
72. On large stocks the commonest form of grafting is the **cleft-graft.** The stock is cut off and split; and in one or both sides a wedge-shaped cion is firmly inserted. Fig. 39 shows the cion; Fig. 40, the cions set in the stock; Fig. 41, the stock waxed. It will be seen that the lower

bud—that lying in the wedge—is covered by the wax; but being nearest the food supply and least exposed to weather, it is the most likely to grow: it will push through the wax.

73. *Cleft-grafting is done in spring, as growth begins. The cions are cut previously, when perfectly dormant, and from the tree which it is desired to propagate.* The cions are kept in sand or moss in the cellar. Limbs of various sizes may be cleft-grafted,—from one-half inch up to four inches in diameter; but a diameter of one inch is the most convenient size. All the leading or main branches of a tree-top may be grafted. If the remaining parts of the top are gradually cut away and the cions grow well, the entire top will be changed over to the new variety.

39. Cion of apple.


40. The cion inserted.


41. The parts waxed.

Review.—How do we determine how a plant may be propagated? Mention any plants that grow from cuttings. What are softwood cuttings? Hardwood? Describe a geranium cutting. What is the proper condition of wood for making a softwood cutting? How is it planted? Where? In what kind of soil? Give directions for watering. How may cutting-wood be secured? Describe a hardwood cutting. When is it made? Name plants which can be propagated easily by means of hardwood cuttings. What is a cion? Stock? How do we find out what stocks are congenial to the cion? Describe a cleft-graft. When is cleft-grafting performed? Why do we graft?

NOTE.—The cutting-box may be set in the window. If the box does not receive direct sunlight, it may be covered with a pane of glass to prevent evaporation. Take care that the air is not kept too close, else the damping-off fungi may attack the cuttings, and they will rot at the surface of the ground. See that the pane is raised a little at one end to afford ventilation; and if water collects in drops on the under side of the glass, remove the pane for a time.

Grafting wax is made of beeswax, resin, and tallow. The hands are greased, and the wax is then worked until it is soft enough to spread. For the little grafting which any pupil would do, it is better to buy the wax of a seedsman. However, grafting is hardly to be recommended as a general school diversion, as the making of cuttings is; and this account of it is inserted chiefly to satisfy the general curiosity on the subject. But now and then a pupil may make the effort for himself, for nothing is more exciting than to make a graft grow all by one's self.

The pictures of the cuttings (Figs. 32–35, 38) and the grafts (Figs. 39–41) are one-third natural size.

Cutting-bed, showing carnations and roses.

CHAPTER VI

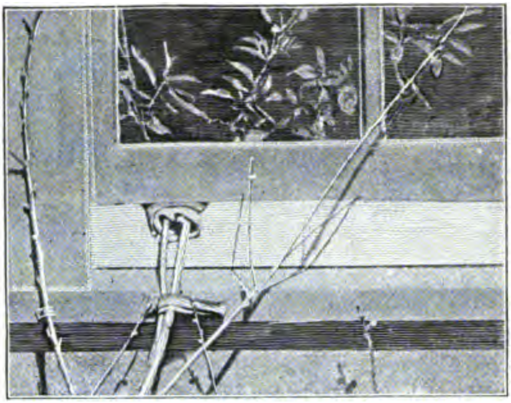
FOOD RESERVOIRS

74. **STOREHOUSES.**—*All greatly thickened or congested parts are* **reservoirs for the storage of plant-food.** This food is mostly starch. Potatoes, beets, turnips, thick rhizomes, seeds, are examples. Recall how potatoes sprout in the cellar (Fig. 42): the sprouts are produced from the stored food.

42. Potato sprouts. The sprouts have used the food stored in the tuber, and the tuber has shrivelled.

75. *The presence of starch can be determined by applying diluted tincture of iodine to the part:* if a blue or

purplish brown color appears, starch is present. Cut the part open and moisten the fresh surface with iodine (to be had at the drug store). The test will usually give the best reaction when the part is perfectly dormant. Starch may be found in nearly all twigs in fall and winter. Test them.



43. A winter branch bearing leaves inside a window, while still attached to the tree outside.

76. *This stored plant-food enables the plant* **to start quickly in the spring,** *without waiting for full root-action to begin; and it enables the plantlet in the seed to grow until it establishes itself in the soil.* The flowers of early-blooming trees are developed mostly from the nourishment stored in the twigs, not from the materials taken in at the time by the roots. This can be demonstrated by bringing branches of peach, apple, and other early-blooming plants into the house in the winter and keeping them in water; they will bloom and sometimes even make leaves. Study Fig. 43.

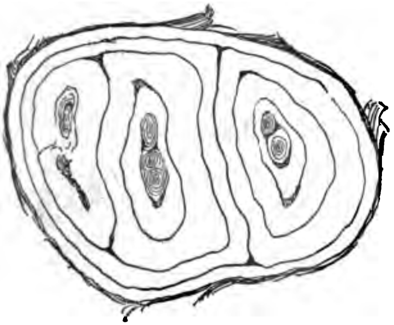
44. Crown tuber.—Turnip.

77. **KINDS OF STOREHOUSES.**— Short and much thickened or swollen parts of roots or stems are known as **tubers.** These may be **stem tubers,** as the potato, or **root tubers,** as the sweet potato (45). Most tubers are subterranean.

45. A multiplier onion.

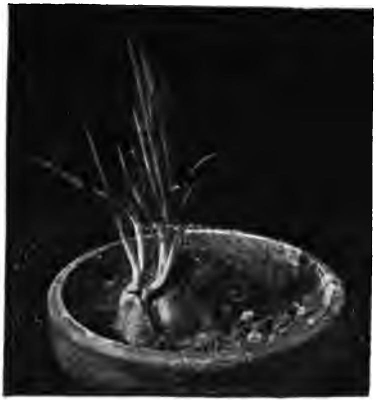
78. Many tubers are stem at the top and root in the remaining part: these are called **crown tubers,** because the upper part comes to the surface of the ground, or is a crown. Leaves and stems arise from the upper part. Beet, radish, parsnip, turnip, salsify, carrot, dahlia roots, are examples. These tubers are usually much longer than broad, and generally taper downwards. Fig. 44.

79. A much thickened part which is composed of scales or plates is a **bulb.** The bulb may be **scaly,** as in the lily; or it may be **tunicated,**—made up of plates or layers within layers, as the onion.



46. Section of a multiplier onion. Natural size.

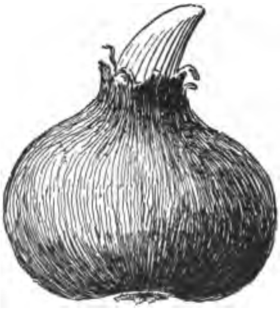
80. Small bulbs which are borne amongst the foliage or flowers are known as **bulblets.** Such are the "top onions," and the little bulbs which the tiger lily (Fig. 30) bears on its stem. Bulbs which grow around the main bulb or which are formed by the breaking apart of the main bulb, are known as **bulbels.** Many bulbous plants propagate by means of bulbels. The



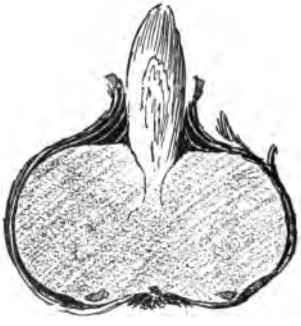
47. Beginning to separate into its parts. Each part will be a little onion.

multiplier or potato onion (Fig. 45) is an example. If the bulb is cut across, it is found to have two or more "hearts" or cores (Fig. 46). When it has been planted a week, each core or part begins to separate (Fig. 47), and there are soon as many onions as there are cores. Potato onions can be bought of seedsmen. They are used for the raising of early onions.

81. Solid bulb-like parts are known as **corms.** These usually have a loose covering, but the interior is not made up of scales or plates. Of such are gladiolus and crocus corms (Figs. 48, 49). Corms multiply by **cormels** or small corms, as bulbs do by bulbels. Fig. 50 shows an old gladiolus corm on which three new corms have grown.



48. Corm of crocus. Nat. size.



49. Section of a crocus corm.

82. We have seen that thickened parts may serve one

or both of two purposes: **they may be storehouses for food; they may be means of propagating the plant.** The storage of food carries the plant over a dry or cold season. By making bulbs or tubers, the plant persists until spring. A lunch is put up for a future day. Most bulbous plants are natives of dry countries.

50. Three corms growing on an old one.—Gladiolus.

REVIEW.—What do you understand by food reservoirs? How is the presence of starch determined? Where may starch be found? Of what service to the plant is this stored food? How are the flowers and leaves enabled to start so early in spring? Define tuber. Root tuber. Stem tuber. Crown tuber. Give examples. Define bulb. Scaly bulb. Tunicated bulb. Bulblet. Bulbel. Give examples. Define corm. Cormel. What two purposes do congested parts serve?

NOTE.—The pupil should examine various kinds of bulbs and tubers. If these are not at hand, many kinds can be bought of seedsmen or florists. Secure onion, narcissus, hyacinth, gladiolus, crocus, potato. Cut them in two. Study the make-up. Test them for starch. Plant some of them in pots or boxes. Observe how they grow. In the onion and some other plants most of the stored food is sugar.

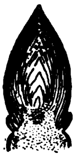
Potato tuber set in a glass of water and kept in a window.

CHAPTER VII

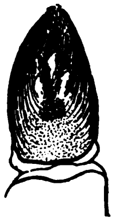
WINTER BUDS

83. **WHAT BUDS ARE.**—Because of cold or dry weather, the plant is forced into a period of inactivity. We have seen that it stores food, and is ready to make a quick start in the spring. It also makes embryo branches and packs them away underneath close-fitting scales: these branchlets and their coverings are **winter buds.** The growing points of the plant are at rest for a time. In the warm season, the growing point is active, and the covering of scales is not so pronounced. *A winter bud may be defined as a resting* **covered growing point.**

84. *A dormant bud, therefore, is a* **shortened axis** *or* **branch,** *bearing miniature leaves or flowers, or both, and protected by a covering.* Cut in two, lengthwise, a bud of the horse-chestnut or other plant which has large buds. With a pin, separate the tiny leaves. Count them. Examine the big bud of the rhubarb as it lies under the ground in winter or early spring. Dissect large buds of the apple and pear. Figs. 51, 52.



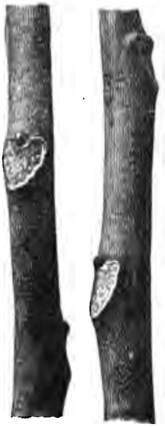
51. Bud of apricot showing the miniature leaves.



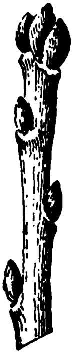
52. Bud of pear showing both leaves and flowers. The latter are the little knobs in the center.

85. *The bud is* **protected** *by firm and dry scales;* but these scales are only modified leaves. The scales fit close. Often the bud is protected by varnish (see horse-chestnut and the balsam poplars). Most winter buds are more or less woolly. Examine them under a lens. As we might expect, bud-coverings are most prominent in cold and dry climates.

86. **WHERE BUDS ARE.**—*Buds are borne in the* **axils of the leaves,**—in the acute angle which the leaf makes with the stem. When the leaf is growing in the summer, a bud is forming above it. When the leaf falls, the bud remains, and a scar marks the place of the leaf. Fig. 53 shows the large leaf-scars of ailanthus. Observe those on the horse-chestnut, maple, apple, pear, basswood, or any tree or bush.



53. Leaf-scars.—Ailanthus.



54. Terminal bud between two other buds.—Currant.

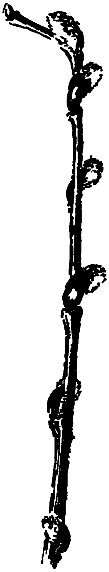
87. Sometimes two or more buds are borne in one axil: the extra ones are **accessory** or **supernumerary buds.** Observe them in the Tartarian honeysuckle (common in yards), walnut, butternut, red maple, honey locust, and sometimes in the apricot and peach.

88. Shoots of many plants bear a bud at the tip: this is a **terminal bud.** *It continues the growth of the axis in a direct line.* Very often three or more buds are clustered at the tip (Fig. 54); and in this case there may be more buds than leaf-scars. Only one of them, however, is strictly terminal.

89. *Bulbs and cabbage heads may be likened to buds:* that is, they are condensed stems, with scales or modified leaves densely overlapping and forming a rounded body. Fig. 55. They differ from true buds, however, in the fact

55. A gigantic bud.—Cabbage.

that they are condensations of main stems rather than embryo stems borne in the axils of leaves. But bulblets may be scarcely distinguishable from buds on the one hand and from bulbs on the other. Cut a cabbage head in two lengthwise, and see what it is like.



56. Willow. The "pussies" are pushing out, and a large black bud-scale is ready to fall from the base of each.

57. Fruit-bud of pear.

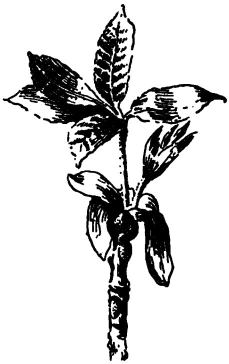
58. The opening of the pear bud.

90. **WHAT BUDS DO.**—*A bud is a* **growing point.** In the growing season it is small, and persons do not notice it. In the winter it is dormant and wrapped up and is plainly seen: it is waiting. *All branches spring from buds.*

91. **All winter buds give rise to branches,** *not to leaves alone:* that is, the leaves are borne on the lengthening axis. Sometimes the axis, or branch, remains very short,—so short that it may not be noticed. Sometimes it grows several feet long.

92. *Whether the branch grows long or not depends on* **the chance it has,** — position on the plant, soil, rainfall, and many other things. The new shoot is the unfolding and enlarging of the tiny axis and leaves which we saw in the bud. Figs. 51, 52. If the conditions are congenial, the shoot may form more leaves than were tucked away in the bud, but commonly

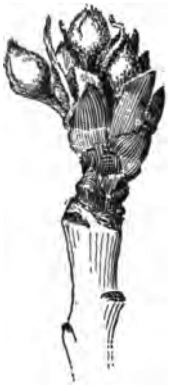
59. Hickory buds.



60. Growth is progressing.

it does not. *The length of the shoot usually depends more on the lengths between joints than on the number of leaves.*

93. **HOW BUDS OPEN.**—*When the bud swells*, **the scales are pushed apart, the little axis elongates and pushes out.** In most plants, the outside scales fall very soon, leaving a little ring of scars. Notice peach, apple, plum, willow, and other plants. Fig. 56. In others, all the scales grow for a time, as in the pear, Figs. 57, 58. In other plants, the inner bud-scales become green and almost leaf-like. See the maple and hickory. Fig. 59 shows a hickory bud. Two weeks later, the young shoot had pushed out and the enlarged scales were hanging (Fig. 60).



61. Opening of the pear bud.

62. A single flower in the pear cluster as seen at 7 A. M. on the day of its opening. At 10 o'clock it will be fully expanded.

94. *Sometimes flowers come out of the buds.* Leaves may or may not accompany the flowers. We saw the embryo flowers in Fig. 52. The bud is shown again in Fig. 57. In Fig. 58 it is opening. In Fig. 61 it is more advanced, and the woolly unformed flowers are appearing. In Fig. 62 the growth is more advanced. In Fig. 63 the flowers are full blown; and the bees have found them.

95. Buds which contain or produce only leaves are **leaf-buds.** Those which contain only flowers are **flower-buds or fruit-buds.** The latter occur on peach, almond, apricot, and many very early spring-flowering plants. Fig. 64. The single flower is emerging from the apricot bud in Fig. 65. Those which contain both leaves and

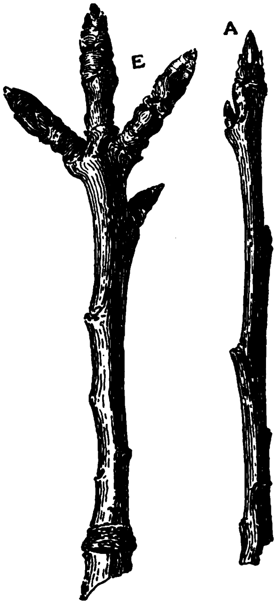
63. Pear in full bloom.

flowers are **mixed buds**, as in pear, apple, and most late spring-flowering plants.

64. Almond flower—the sole occupant of a bud.

65. The opening of the flower-bud of apricot.

96. *Fruit-buds are usually* **thicker or stouter** *than leaf-buds. They are borne in* **different positions on different plants.** In some plants (apple, pear) they are on the ends of short branches or spurs; in others (peach, red maple) they are along the sides of the last year's growths. In Fig. 66 are shown three fruit-buds and one leaf-bud on E, and leaf-buds on A. In Fig. 67 a fruit-bud is at the left, and a leaf-bud at the right.



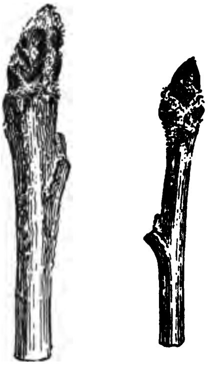
66. Fruit-buds and leaf-buds of pear.

97. **THE "BURST OF SPRING"** means chiefly the opening of the buds. **Everything was made ready the fall before.** *The embryo shoots and flowers were tucked away, and the food was stored.* The warm rain falls, and the shutters open and the sleepers wake: the frogs peep and the birds come.

REVIEW.—What are dormant buds? What are they for? What is their covering? Where are they borne? When are they formed? What is a leaf-scar? What are accessory buds? What other name is applied to them? Define terminal bud. What does it do? What are bulbs and cabbages? How do they differ from buds? What do buds do? From what do branches arise? To what do winter buds give rise? What determines whether the branch shall be long or short? Describe the opening of a bud. What are flower-buds? Leaf-buds? Mixed buds? How may fruit-buds be distinguished? What is the "burst of spring"?

NOTE.—It is easy to see the swelling of the buds in a room in winter. Secure branches of trees and shrubs, two to three feet long, and stand them in vases or jars, as you would flowers. Renew the water frequently and cut off the lower ends of the shoots occasionally. In a week or two the buds will begin to swell. Of red maple, peach, apricot, and other very early-flowering things, flowers may be obtained in ten to twenty days. Try it.

The shape, size, and color of the winter buds are different in every kind of plant. By the buds alone botanists are often able to distinguish the kinds of plants. Even such similar plants as the different kinds of willows have good bud characters. The study of the kinds of buds affords excellent training of the powers of observation.



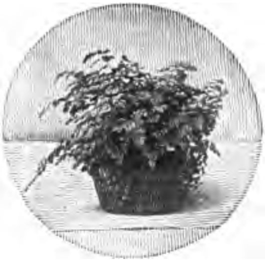
67. Fruit-bud and leaf-bud of apple.

The burst of spring in the lilac.

CHAPTER VIII

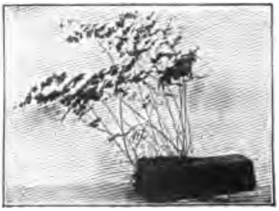
PLANTS AND SUNLIGHT

98. **EACH PLANT LOOKS FOR LIGHT.—Green plants live only in sunlight,** direct or indirect. The gradual withdrawal of light tends to weaken the plant; but the plant makes an effort to reach the light and therefore grows towards it. *The whole habit of a plant may be changed by its position with reference to sunlight.* Select two similar plants. Place one near the window and the other far from it. Watch the behavior from day to day. Fig. 68 shows a fern which grew near the glass in a conservatory: Fig. 69 shows one which grew on the floor of a conservatory. Fig. 69 also teaches another lesson, which is to be explained in another chapter (Chapter XXVI).

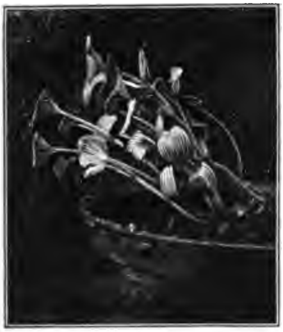

68. Sufficient light.

99. **Plants grow towards the light.** *The most vigorous branches, as a rule, are those which receive most light.* Climb a tree and observe where the thriftiest shoots are; or observe any bush.

100. When plants or their parts are not stiff or rigid, *they turn towards the light if the light comes mostly from one direction.* The geraniums and fuchsias in the window are turned around occasionally so that they will grow symmetrical. Plant radish in a


69. In need of light. Same kind of fern as No. 68.

pot or pan. When the plants are three or four inches high, place the pan in a tight box which has a hole on one side. The next day it will look like those in Fig. 70. This turning towards the light is called **heliotropism** (*helios* is Greek for "sun.")


70. Searching for light.

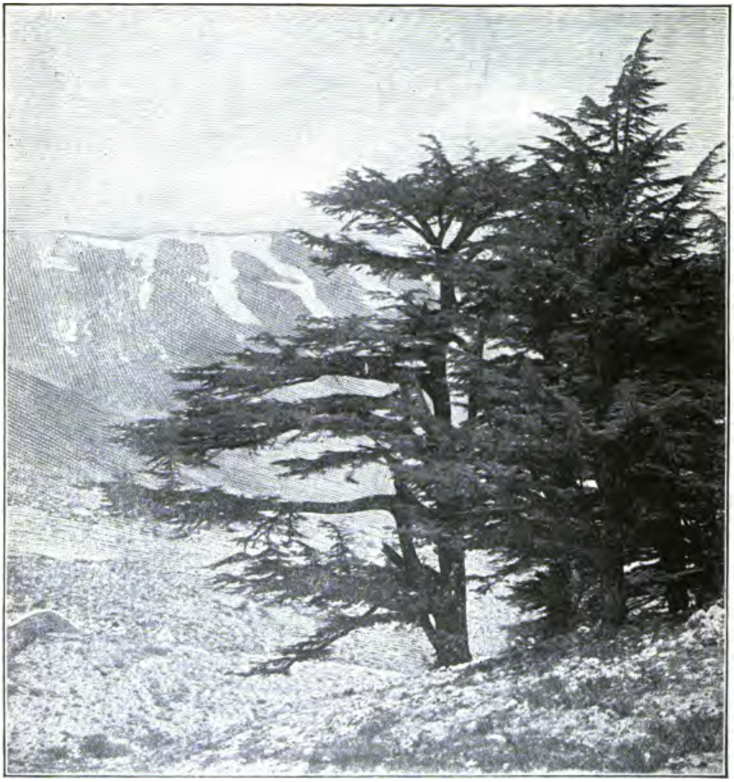
101. *Even under natural conditions, plants become misshapen or unsymmetrical if the light comes mostly from one direction.* On the edge of a forest, the branches reach out for light (Fig. 71). Trees tend to grow away from a building. Branches become fixed in their position, so that even in winter they tell of the search for light (Fig. 72).

102. *Some plants climb other plants* **in order to reach the sunlight;** *or they climb rocks and buildings.* Notice that the vine on the house luxuriates where it is lightest. Climbing plants sometimes choke and smother the plant on which they climb. This they may do by throwing their mantle of foliage over it, and smothering it, or by sending their roots into its trunk and robbing it of food. Sometimes they do both, as in Fig. 74. **Every plant has a story to tell of the value of sunlight.**

103. **EACH BRANCH LOOKS FOR LIGHT.**—The plant is made up of branches. **There is a struggle amongst the branches for sunlight.** We have seen (Fig. 7) that no two branches are alike: we now know one reason why. Notice that the small branches die in the center of the tree. Look on the inside of a pine, spruce or other dense tree. **Every branch has a story to tell of the value of sunlight.**

104. **EACH LEAF LOOKS FOR LIGHT.—Leaves are borne towards the ends of the branches.** This is particu-

larly marked when the struggle is severe. If the outside of a plant is densely thatched with leaves, the inside will be found to be comparatively bare. Contrast Figs. 75 and 76, both being views of one tree. We know the tree as seen in Fig. 75: the squirrel knows it as seen in Fig. 76.



71. Branches of the cedar reaching for light.

105. On any branch in a very thick-topped tree or bush, leaves of equal age usually tend to be **largest where**

72. The branches have grown towards the light.

the light is best. Leaves which grow in full sunlight tend to persist later in the fall than those which grow in poor light (Fig. 77). This fact is sometimes obscured because the outermost leaves are most exposed to autumn winds.

106. Plants which start in cellars, from seeds, bulbs, or tubers, grow until the stored food is exhausted and then die: the **leaves do not develop to full size in darkness.** Figs. 78 and 79 show this. Fig. 78 is rhubarb forced in a cellar for the winter market; Fig. 79 is a plant grown out-of-doors. Compare Fig. 42.

73. Mantle of clematis. The leaves, and later the flowers, spread themselves to the light.

107. *The* **position** *or* **direction** *of leaves is determined largely by exposure to sunlight.* In temperate climates, they usually hang in such a way that they receive the greatest amount of light. Observe the arrangement of leaves in Fig. 80. One leaf shades the other to the least possible degree. If the plant were placed in a new position with reference to light, the leaves would make an effort to turn their blades. Observe the shingle-like arrangement

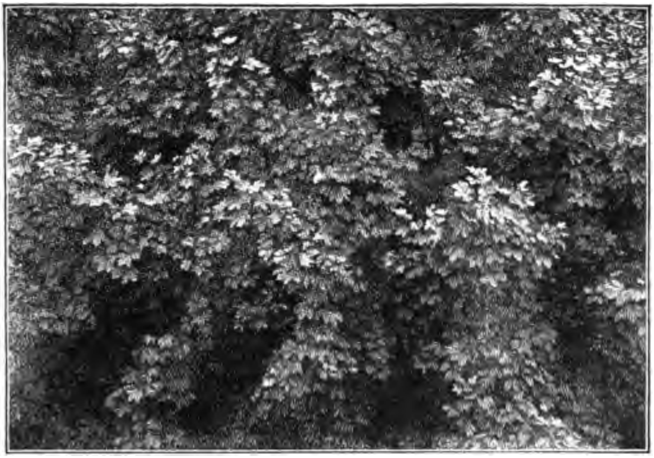
in Fig. 75. If the pupil were to examine the leaves on the Norway maple, which is photographed in Fig. 75, he would find that leaves which are not on the outside lengthen their leaf-stalks in order to get the light. See Fig. 144. Norway maple is common on lawns and roadsides.

108. We have seen (84) that a large part of the leaves of any one year are packed away in the buds of the previous winter. It is almost impossible that these leaves should be packed away hit or miss. *They are usually arranged in a* **mathematical order.** We can see this order when the shoot has grown. We can see it by studying the buds on recent shoots, since there was a leaf for each bud. The leaves (or buds) may be **opposite** *each other on the stem, or* **alternate.** Fig. 81.

74. A climbing fig choking a palm.

109. *When leaves are opposite, the pairs usually alternate.* That is, if one pair stands north and south, the next pair stands east and west. See the box-elder shoot, on the left in Fig. 81. *One pair does not shade the pair beneath.* The leaves are in four vertical ranks.

110. *There are several kinds of* **alternate** *arrangement.* In the elm shoot in Fig. 81, the third bud is verti-



75. Looking at the top of a Norway maple.—As the bird sees it.

76. Looking up into the same tree.—As the squirrel sees it.

77. A maple tree on the south side of a grove. On the south side the leaves hung four weeks longer than on the north side, because of more sunlight and perhaps more food.

cally above the first. This is true, no matter which bud is selected as the starting point. Draw a thread around the stem until the two buds are joined. Set a pin at each bud. Observe that two buds are passed (not counting the last) and that the thread makes one circuit of the stem. Representing the number of buds by a denominator, and the number of circuits by a numerator, we have the fraction $\frac{1}{2}$, *which expresses the part of the circle which lies between any two buds*. That is, the buds are one-half of 360 degrees apart, or 180 degrees. Looking endwise at the stem, the leaves are seen to be 2-ranked. Note that in the apple shoot (Fig. 81, right), the thread makes two circuits and five buds are passed: two-fifths represents the divergence between the buds. The leaves are 5-ranked.

78. Rhubarb grown in the dark. The leaf-blades do not develop.

111. *Every plant has its own arrangement of leaves.* For opposite leaves, see maple, box-elder, ash, lilac, honeysuckle, mint, fuchsia. For 2-ranked arrangement, see all grasses, Indian corn, basswood, elm. For 3-ranked arrangement, see all sedges. For 5-ranked (which is one of the commonest), see apple, cherry, pear, peach, plum, poplar, willow. For 8-ranked, see holly, osage orange. More complicated arrangements occur in bulbs, house leeks, and other condensed parts. *The arrangement of leaves on the stem is known as* **phyllotaxy** (literally "leaf-arrangement".) Make out the phyllotaxy on any plant.

79. Rhubarb grown in the light.

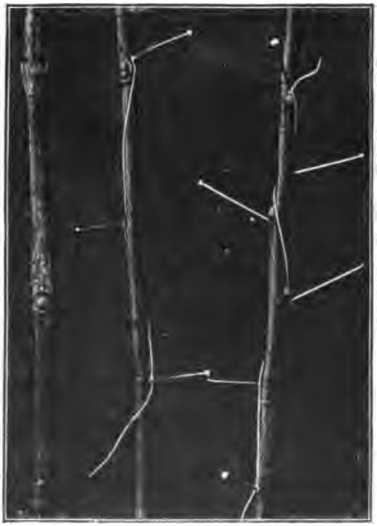
112. In some plants, several leaves occur at one level, being arranged in a circle around the stem. Such leaves are said to be **verticillate or whorled.** Leaves arranged in this way are usually narrow.

113. Although a definite arrangement of leaves is the rule in most plants, **it is subject to modification.** On shoots which receive the light only from one side or which grow in difficult positions, the arrangement may not be definite. Examine shoots which grow on the under side of dense tree-tops or in other partially lighted positions.

114. The direction or "hang" of the leaf is usually fixed, but *there are some leaves which change their direction* **between daylight and darkness.** Thus, leaves of clover (Fig. 82), bean, locust, and many related plants, "sleep" at night; also oxalis. It is not a sleep in the sense in which animals sleep, however; but its function is not well understood.

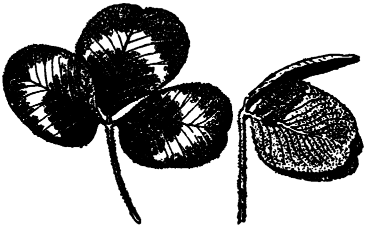
80. All the leaves are exposed to light.

115. *Leaves usually expose* **one particular surface** *to the light.* This is because their internal structure is such that light is most efficient when it strikes this surface, as we shall learn later on. *Some plants, however, expose both surfaces to the light, and their leaves stand vertical. Others endeavor to avoid the intense light of mid-day and to turn in the direction of least light.* Leaves standing edgewise are said to exhibit polarity. They are "compass plants" if they point north and south. The famous compass plant or silphium of the prairies and the wild lettuce are examples of plants having polar leaves. (Wild lettuce [Lactuca Scariola] is a common plant on roadsides; p. 356.) **Every leaf has a story to tell of the value of sunlight.**



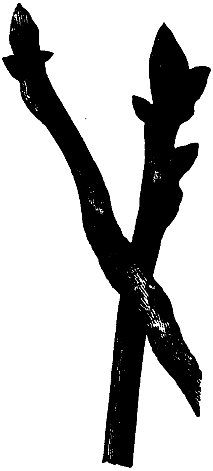
81. Phyllotaxy of box-elder, elm, apple.

116. **WINTER BUDS SHOW WHAT HAS BEEN THE EFFECT OF SUNLIGHT.**—Buds are borne in the axils of the leaves (86), and *the size or vigor of the leaf determines to a large extent the* **size of the bud.** Notice that, in most instances, *the largest buds are nearest the tip* (Fig. 83). If the largest ones are not near the tip, there is some special reason for it. Examine the shoots on trees and bushes.



82. Day and night positions of the clover leaf.

117. *The largest buds usually start first in spring*, and the branches which arise from them have the advantage in the struggle for existence. *Plants tend to grow most vigorously* **from their ends.** Observe that only the terminal bud grew in the hickory twig in Fig. 60. **Every bud has a story to tell of the value of sunlight.**



83. The big terminal buds.—Hickory.

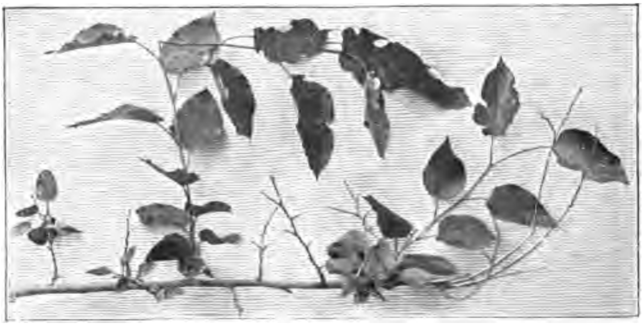
REVIEW.—What is the relation of the plant to sunlight? Does its form ever depend on its relation to light? In what direction do the tops of plants grow? Where are the most vigorous branches? What is heliotropism? Why are trees sometimes unsymmetrical? Do you know any instances yourself? What is one way in which plants profit by the climbing habit? Is there struggle amongst branches? Explain. Where are leaves borne in reference to light? Where are leaves usually largest? Do they develop in darkness? Are leaves borne directly above one another? How may leaves be arranged? Explain what phyllotaxy is. Are leaves always arranged definitely? Explain the arrangement in some plant which is not mentioned in this lesson. What is the "sleep" of leaves? Which surface of the leaf is exposed? What are compass plants? How do buds show what the effect of sunlight has been? What buds start first in spring?

CHAPTER IX

STRUGGLE FOR EXISTENCE AMONGST THE BRANCHES

118. **NO TWO BRANCHES ARE ALIKE.**—*Every twig has a history. It has to contend for air and sunlight, and a place in which to grow. Its size and shape, therefore, depend on the* **conditions under which it lives.** Observe the long, straight, big-leaved shoots on the top of the plant, and the short, weak, crooked ones on the inside or under side.

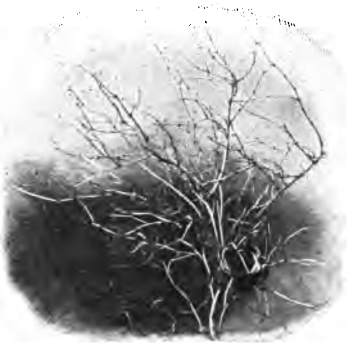
119. *There is* **struggle for existence** *for every twig and every leaf.* Those finding the best conditions live and thrive; those finding the poorest die. The weak are overpowered and finally perish: this prunes the tree, and tends to make the strong the stronger. Observe the competition in the branch photographed in Fig. 84. Pick out the dead twigs, the weak ones, the strong ones.



84. The struggle for life.—Mulberry shoot.

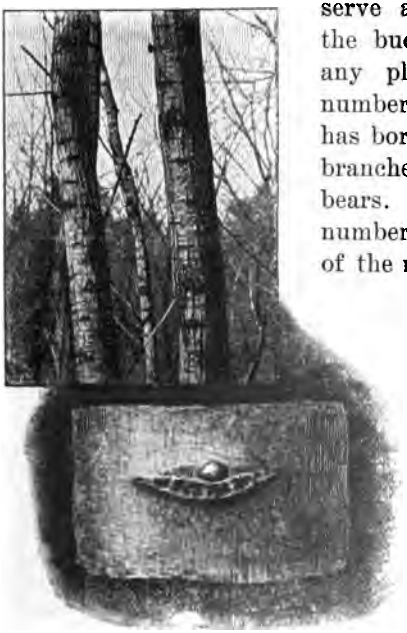
120. **THE BUDS MAY NOT GROW.**—*There is* **not room in a tree-top** *for all the buds to grow into branches.* Some buds

are suppressed. Branches die. So it comes that branches are not arranged regularly, although the buds may be. In the Tartarian or "tree" honeysuckle the buds are opposite; Fig. 85 shows how the branches are.



85. The branching is crooked and irregular.

121. *The results of the struggle for existence in the tree-top can be expressed in figures.* Consider that every bud is the germ or starting point of a branch. Observe at what distances apart the buds are usually borne on any plant, and estimate the number of buds which the plant has borne: count the number of branches which the tree actually bears. It will be found that the number of buds is far in excess of the number of branches: the difference between the numbers shows how many buds or branches have failed. Or, count the buds on any branch, and figure up the possibilities. A branch 12 inches long, for instance, has 10 buds. If each bud grows, at the end of the next season there



86. Scars of the dormant buds.—Willow.

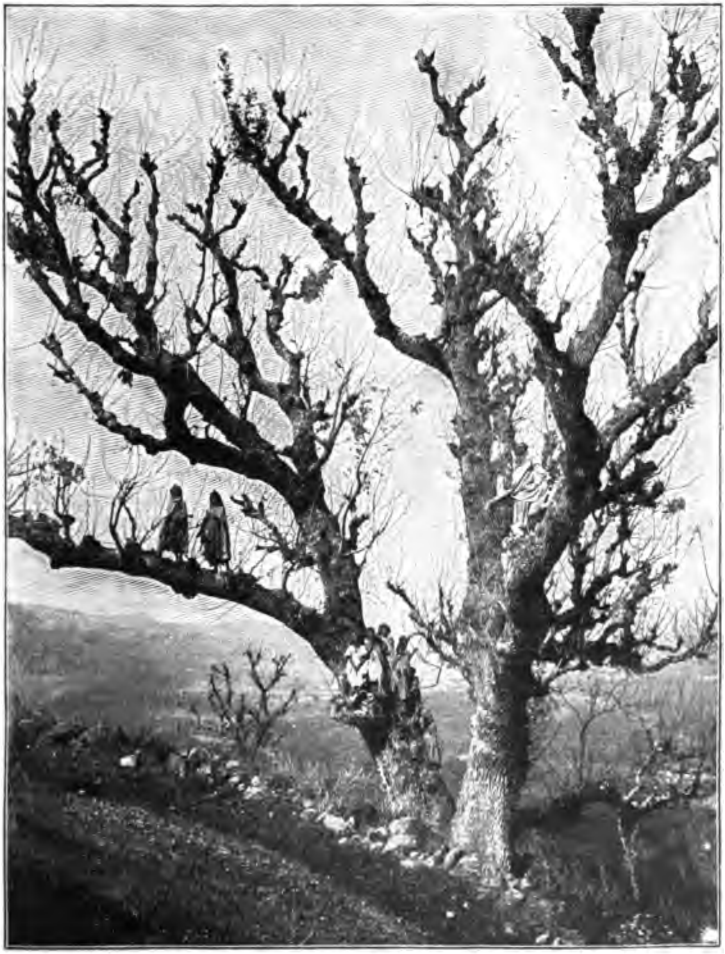
will be 10 branches, each of which may have 10 buds. At the end of the second year there will be 100 branches; at the end of the third, 1,000. Can 1,000 branches be borne on a 4-year-old branch 12 inches long? Or, count the old bud-scars on the branches—*for the places of the buds persist as wrinkles in the bark*, often for many years (Fig. 86). One can often locate these bud-scars on old branches with his eyes closed by running his fingers over the bark.

122. Buds which fail to grow are called **dormant buds.** *They are usually the weakest ones,—those which grew in the most uncongenial conditions.* They are towards the base of the shoot. We have seen (117) that it is the terminal or uppermost buds which are most likely to grow. The dormant buds gradually die. They may live four or five years on some plants. If the other buds or branches fail or are injured, they may grow, but usually they die.

123. Dormant buds must not be confounded with adventitious buds. We have learned (54) that **adventitious buds** *are those which are formed at unusual times or places, because of some disturbance of the part.* If a large branch is cut off, suckers or watersprouts are thrown out near the wound: these arise from buds which are *made for the occasion.* These buds did not exist there. In many countries it is a custom to "pollard" or cut off the tops of trees every few years for the firewood; and strong adventitious shoots arise along the trunk. Fig. 87.

124. **WHERE THE BRANCHES GROW.**—Because new shoots tend to arise from the top of the twigs, *the branches of most trees are in* **tiers** *or* **layers.** These tiers often can be traced in trees 50 and 100 years old. Try it in any oak, maple, ash, or other tree. For practice, begin with young, vigorous trees (Figs. 88 and 89).

125. *When part of a top is removed, the remaining*

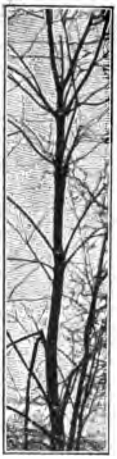


87. A pollard tree

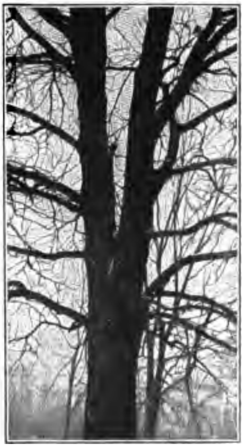
In this case, man has added to the struggle for existence.

branches fill the space. The branches are attracted by the light and air, and grow in that direction. *A pruned or injured top always tends to come back to* **equilibrium.**

126. *A mangled or broken plant tends to regain its former* **position.** From fallen trees, upright shoots arise. In Fig. 90 observe the new trunk arising from the center of the arch; see that the main trunk is smaller beyond that point.



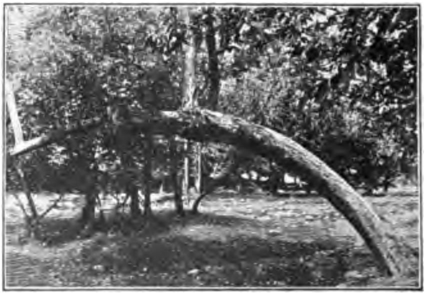
88. Tiers of branches on young tree.



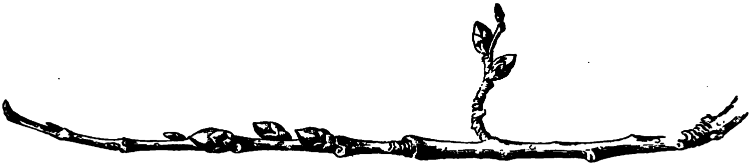
89. Even in old trees the tiers can be traced.

REVIEW.—What is meant by the statement that every twig has a history? Upon what does the shape and size of a branch depend? Explain what you mean by the struggle for existence. Why do not all buds grow? If buds are arranged in mathematical order, why are not branches? How may the effect of struggle for existence be expressed in figures? Select some branch and explain. Define dormant buds. Adventitious buds. Why are branches in tiers, or borne at intervals? How do plants tend to regain their form and position, when injured?

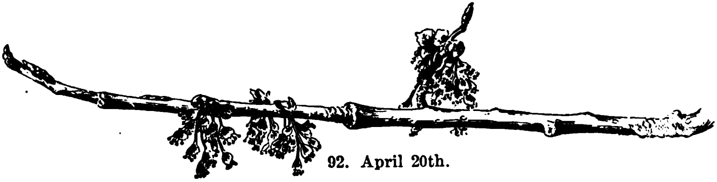
NOTE.—Let the pupil work out the history of some branch. It is better to select a branch which is vigorous. He should first determine, if the shoot is dormant, how much grew the previous season. The last year's growth bears buds on the



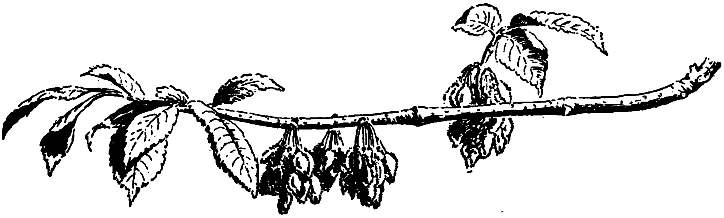
90. The erect bole on the fallen trunk.



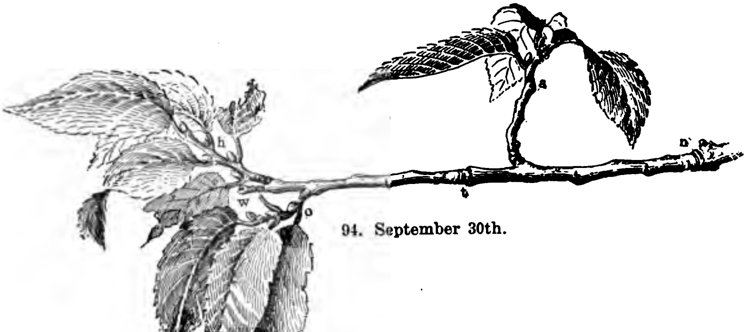
91. An elm shoot, April 10th.



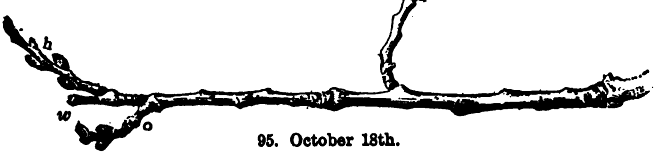
92. April 20th.



93. May 20th.



94. September 30th.



95. October 18th.

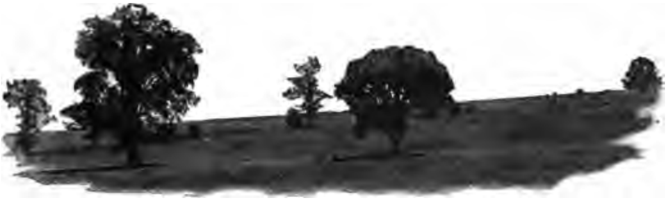
main axis, not on side branches; and the "ring" (scars of bud-scales) marks the junction between the different years' growth. Notice this ring in Fig. 83. The teacher will find many twigs worked out in "Lessons with Plants." Figs. 91–95 show an actual case. These drawings were all made with the greatest care from one elm twig. The twig (Fig. 91) shows three years' growths. The side branch is evidently only one year old, for it did not arise until the twig which bears it was one year old. Note that only one of the buds made a branch. There are five blossom buds. Fig. 92 shows the twig in bloom. Fig. 93 shows it in fruit and leaf. Fig. 95 shows the net result. The side branch grew from *a* to *s* and made two blossom buds. The tip of the main shoot (Fig. 91) was broken in a storm. The two buds next in succession grew. Each made flower buds. Observe how many buds on this elm shoot have failed.

Crushed by storm, the tree still shoots upward.

CHAPTER X

THE FORMS OF PLANTS

127. Although the form of the branch, and to some extent the entire plant, is determined by a struggle with the conditions in which it grows, nevertheless *each kind of plant has its* **own peculiar habit of growth.** The lumberman distinguishes the kinds of trees by their "looks," rather than by their leaves or flowers, as the botanist does. The farmer usually does the same with his cultivated plants.



96. Different forms of trees.

128. The habit of a plant is determined by its *size, general style or direction of growth, form of head, and method of branching.* The general style or stature of plants has been mentioned in Chapter III—they may be erect, strict, creeping, decumbent, and the like. The shape of the top or head is well illustrated in trees. Note the general effect of the mass, as seen at a distance. The elm is **vase-form** or **round-headed** (Fig. 96, which is cited again to teach another lesson, p. 223). So

97. Round-headed and fastigiate trees.

are maple, beech, and apple trees. The Lombardy poplar (Fig. 97) is **columnar or fastigiate.** Young spruces and firs are **conical.** Heads may be **narrow, wide, flat, symmetrical, irregular or broken.**

98. The unbranched trunks of palms.

129. *The general leafage or furnishing of the top is different for each kind.* The top may be **dense** or **thin.** The foliage may be **heavy, light, large, small.** Compare maples and elms, apples and peaches, and other trees.

130. *The* **trunk** *or* **bole** *of the tree is one of its most conspicuous features.* Observe the strict straight trunk of the palm (Fig. 98), and the forking trunks of elms and maples. Observe that no two trees have trunks which are quite alike. *The* **bark** *is different for each kind of plant.*

99. The plant form in winter.—Russian thistle.

131. Plants awaken certain thoughts or feelings: they are said to have **expression.** This expression is the source of much of our pleasure in them. Trees are particularly expressive. One suggests *restfulness*, because of its deep shady top; another *gaiety*, from its moving,

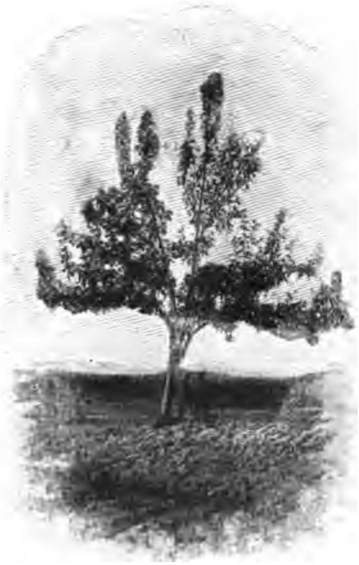
small, light-colored leaves; another *heaviness*, from its very large, dull foliage; another *strength*, from the massive branches; another *grace*, from the flowing outline or flexile growth. We think of the oak as strong, the willow as lithe, the aspen as weak, and the like. Irregular or gnarly trees suggest struggle. *If all plants, or even all trees, were alike, we should have little pleasure in them.*

100. The many trunks of an old olive tree. Italy.

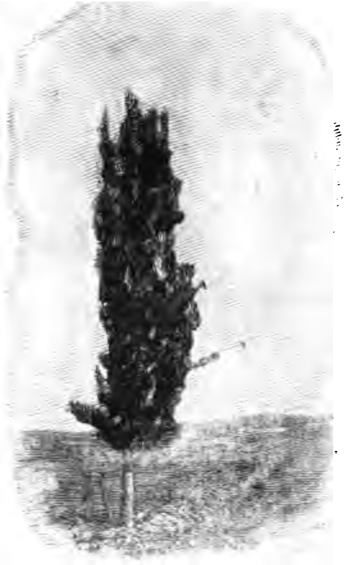
132. *The expression of a plant depends to some extent on the* **character of the shadows in the top.** These shadows (or lights and shades) are best seen by looking at the plant when the sun is low and behind the observer.

Stand at some distance. Look at the dark places in the old pasture maple: they are lumpy and irregular. In the pasture beech they are in layers or strata. *The shadows depend mostly on the method of branching.* Those who take photographs know how the "high lights" and shadows develop on the plate.

133. *The habit of a plant is usually* most apparent when it is leafless. The framework is then revealed. *Woody plants are as interesting in winter as in summer.* Observe their forms as outlined against the sky—every one different from every other. Notice the plant forms as they stand in the snow. Fig. 99. How do stems of the pigweed differ from those of burdock and grasses? Observe how the different plants hold snow and ice.



101. A pear tree of the Kieffer variety.



102. A pear tree of the Hardy variety.

134. *The more unusual the shape of any tree or other*

plant, the greater is our interest in it, because our curiosity is awakened. Some unusual circumstance or condition has produced the abnormal form. Such plants should be preserved whenever possible. Fig. 100.

REVIEW.—What do you mean by the statement that each kind of plant has its own habit (36)? How do plants differ in habit? Name some of the forms of tree-tops. How may plants differ in the furnishing of the top? Is the trunk characteristic? Bark? Bring in and describe the bark of three kinds of trees. What is the expression of a tree? What are some of the expressions? Explain what you understand by the shadows in the top. On what do the shadows chiefly depend? What is there to see in plants in winter? Why are we interested in plants of unusual form? Tell how any two trees differ in "looks."

NOTE.—One of the first things the pupil should learn about plants is to see them *as a whole.* He should get the *feeling of mass.* Then he should endeavor to determine why the mass is so and so. Trees are best to begin on. No two trees are alike. How do they differ? The pupil can observe as he comes and goes from school. An orchard of different kinds of fruits shows strong contrasts. Even different varieties of the same fruit may be unlike in habit. This is especially true in pears (Figs. 101, 102).

A honey locust tree.

CHAPTER XI

HOW THE PLANT TAKES IN THE SOIL WATER

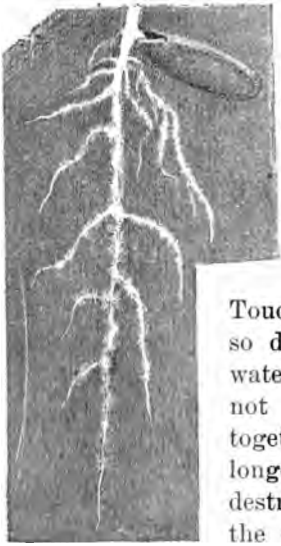
135. **PLANT-FOOD.**— Having learned what a plant is and having seen it as a whole, we may now inquire how it secures food with which to live. We can discuss only the outlines of the subject here: the pupil may consider the question again when he takes up Part III. *The plant obtains food materials* **from the soil.** We know this to be true, because the plant dies if removed from the soil. In this discussion, we use the word food to designate *any material which the plant takes in to incorporate with its tissues or to aid in promoting its vital activities.* The word is sometimes used to denote only some of the products (as starch) which the plant manufactures from the raw materials, but it is unfortunate to press a common-language word into such technical use.

136. **ROOT STRUCTURE.**—*Roots divide into the* **thinnest and finest fibrils:** *there are roots and there are rootlets.* The large, fleshy root of the radish (Fig. 103) terminates in a common-sized root to which little rootlets are attached. Then there are little rootlets attached to the fleshy root at various places near the base. But the rootlets which we see are only intermediary, and there are numerous yet smaller structures.

103. Root and rootlets.

137. *The rootlets, or fine divisions, are clothed with* **root-hairs** (29), *which are very delicate structures.* Carefully

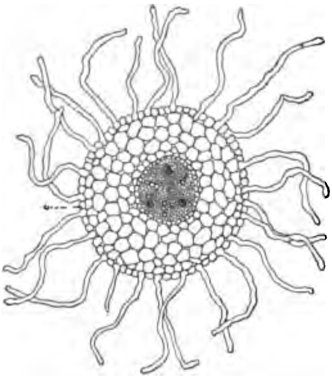
germinate radish or other seed, so that no delicate parts of the root will be injured. For this purpose, place a few seeds in packing-moss or in the folds of cloth or blotting paper, being careful to keep them moist. In a few days the seed has germinated, and the root has grown an inch or two long. Notice that, excepting at a distance of about a quarter of an inch behind the tip, the root is covered with minute hairs (Figs. 11, 104). They are actually hairs, that is, root-hairs. Touch them and they collapse, they are so delicate. Dip one of the plants in water, and when removed the hairs are not to be seen. The water mats them together along the root and they are no longer evident. Root-hairs usually are destroyed when a plant is pulled out of the soil, be it done ever so carefully. They cling to the minute particles of soil. Under a microscope, observe how they are flattened when they come in contact with grains of sand (Chapter II). *These root-hairs clothe the young rootlets, and* **a great amount of soil is thus brought into actual contact with the plant.** *Root-hairs are not young roots: they soon die.*



104. Root of pumpkin seedling, showing the covering of root-hairs.

138. *The rootlet and the root-hair differ.* The rootlet is a solid, **compact structure.** *The root-hair is* **a delicate tube** (Fig. 105), *within the cell-wall of which is contained living matter (protoplasm); and the lining membrane of this wall permits water and substances in solution to pass in.* Being long and tube-like, these root-hairs are especially adapted for taking in the largest quantity of solu-

tions; and they are the principal means by which plant-food is absorbed from the soil, although the surfaces of the rootlets themselves do their part. Water-plants do not need an abundant system of root-hairs, and such plants depend largely on their rootlets.

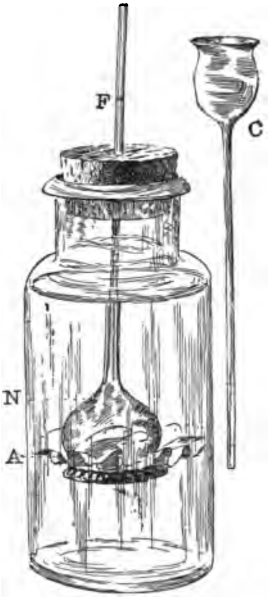


105. Cross section of root, enlarged, showing root-hairs.

139. **OSMOSIS.**—In order to understand how the water enters the root-hair, it is necessary that we study the physical process known as osmosis. *A salt solution separated by a membrane from water absorbs some of the water and increases its own volume.* First dissolve one ounce of saltpeter, which we may use as a fertilizer solution, in one pint of water, calling this solution No. I. For use in experiments later on, also dissolve a piece of saltpeter not larger than a peach pit (about one-seventh ounce) in about one gallon of water, calling this solution No. II. Now fill the tube, C in Fig. 106, almost full of the strong solution I, and tie a piece of animal membrane (hog's bladder is excellent for this purpose) over the large mouth. A small funnel, with a long stem, may be used if one cannot obtain a tube like C. Then sink the tube, bladder-part downwards, into a large bottle, A, of water until the level of liquid in the tube stands at the same height as that in the bottle. The tube may be readily secured in this position by passing it through a hole in the cork of the bottle. In a short time, we notice that the liquid in N begins to rise, and in an hour or so it stands as at F, say. This is an important result. The liquids diffuse. The salt in the solution diffuses more slowly than the water. If water

were on both sides of the membrane, it would diffuse equally both ways and there would be no rise of liquid. The presence of salt in N diminishes the amount of fluid passing out, and more water comes in than water and salt go out; hence there is pressure in the tube.

140. *The cell-sap of the root-hair absorbs water from the soil by* **osmotic action.** The above experiment enables us to understand how the countless little root-hairs act,— each one like the tube N, if only the whole surface of the tube were a bladder membrane, or something acting similarly. The soil water does not contain much of the land's fertility: that is, it is a very weak solution. The active little root-hair, on the other hand, is always filled with cell-sap, a more concentrated solution: hence soil water must come in, and along with it come also small quantities of dissolved food materials. Some of these materials may be fertilizers which have been applied to the land.



106. To illustrate osmosis.

141. *The plant absorbs these solutions* **as long as they are used for the growth of the plant.** The salts which are dissolved in the soil water diffuse themselves through the tiny membrane of the root-hairs, each ingredient tending independently to become as abundant inside the root-hair as outside in the soil water. Once inside the root-hair, these absorbed solutions pass on to root and stem and leaf, to be utilized in growth. As long as they are used, however, more must come into the root-hairs, in order *to restore the equilibrium. Thus those substances which are*

needed must come in as long as the land can furnish them in soluble form. Absorption was illustrated before by an artificial arrangement because the root-hairs are so small that they cannot be seen readily. **But all parts of the root can absorb some water.**

142. *Fleshy pieces of root or stem will absorb water from weak solutions and become rigid; in strong solutions such fleshy parts will give up their water and become flexible.* To experiment further with this principle of absorption, cut several slices of potato tuber about one-eighth of an inch in thickness, and let them lie in the air half an hour. Place a few of these slices in some of the strong fertilizer solution I. Place similar pieces in the weak solution II. In half an hour or more, those pieces in the weak solution will be very rigid or stiff (turgid). They will not bend readily when held lengthwise between the fingers. Compare these slices with those in the strong solution, where they are very flexible (flaccid). This bending is evidently due to the fact that those in the strong brine have actually lost some of their water. So the potato tuber could take in soil water containing a small amount of food; but if the water contained much food material the potato would actually **lose some of the water which it held.**

107. Killed by too strong food solution.

143. These experiments not only demonstrate how the roots absorb water containing plant-food, but they emphasize the fact that the outside **solution must be very dilute** *in order that water may be absorbed at all. The root-hairs absorb water which has dissolved only a small amount of plant-food from the richness of the soil, and not from such rich solutions as the sap of the plant itself.*

144. *The plant may be wilted, and even killed by attempting to feed it food solutions which are* **too strong.**

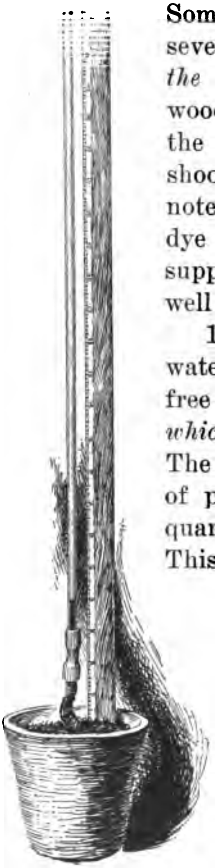
To test this matter, secure a young radish plant (or almost any seedling with several leaves) and insert the roots into a small bottle containing some of the saltpeter solution I. In another bottle place a similar plant with some of the weak solution II. Support the plant in the mouth of the bottle with cotton batting. After standing for a few hours or less it will be noticed that the leaves of the plant in the strong solution begin to wilt, as in Fig. 107. The plant in the weak solution, Fig. 108, is rigid and normal. This further indicates that the growing plant is so constituted as to be able to make use of very dilute solutions only. If we attempted to feed it strong fertilizer solutions, these strong solutions, instead of being absorbed by the plant, take water from the latter, *causing the plant to wilt.*

108. The plant thrives in a weak solution.

145. *The farmer or gardener knows that he can injure or even kill his plants by adding* **too much plant-food.** Everyone recognizes the value of wood ashes as a fertilizer; but no one would dare water his valuable plants with lye, or sow his choice vegetable seeds on an ash bank, however well it might be watered. If there is a potted plant at hand which is of no value, remove some of the soil, add considerable wood ashes, water well, and await the result; or give it a large lump of nitrate of soda.

146. **ROOT-PRESSURE.**—*The activity of the root in absorbing water gives rise to* **considerable force.** This force is known as **root-pressure.** The cause of this pressure is not well understood. The pressure varies in different plants and in the same plant at different times. To illustrate root-pressure, cut off a strong-growing small plant near the ground. By means of a bit of rubber tube,

attach a glass tube with a bore of approximately the diameter of the stem. Pour in a little water. Observe the rise of the water due to the pressure from below (Fig. 109). Some plants will force the column of water several feet. The water ascends chiefly in *the young wood*, not between the bark and wood, as commonly supposed. To illustrate the path of water-ascent, insert a growing shoot in water which is colored with eosin: note the path which the color takes. (Eosin dye may be had of dealers in microscope supplies. Common aniline may answer very well.)



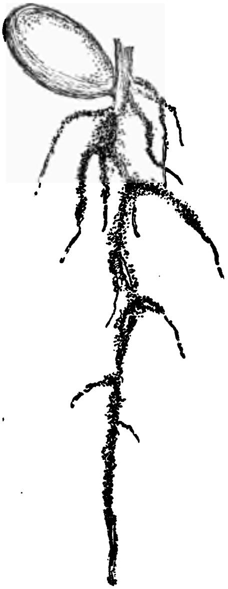
109.
To show root-pressure.

147. **HOW THE SOIL HOLDS MOISTURE.**—The water which is valuable to the plant is not the free water, but the **thin film of moisture** *which adheres to each little particle of soil.* The finer the soil, the greater the number of particles, and therefore the greater is the quantity of film moisture which it can hold. This moisture surrounding the grains may not be perceptible, yet the plant can use it. *Root absorption may continue in a soil which seems to be dust dry.*

148. **THE ROOTS NEED AIR.** — Corn on land which has been flooded by heavy rains loses its green color and turns yellow. *Besides diluting plant-food, the water drives the air from the soil, and this* **suffocation of the roots** *is very soon apparent in the general ill health of the plant.* Stirring or tilling the soil aërates it. Water-plants and bog-plants have adapted themselves to their particular conditions. They either get their air by special surface roots, or from the water.

149. **PROPER TEMPERATURE.**—*The root must be warm in order to perform its functions.* Should the soil of fields or greenhouses be much colder than the air, the plant suffers. When in a warm atmosphere, or in a dry atmosphere, plants need to absorb much water from the soil, and the roots must be warm if the root-hairs are to supply the water as rapidly as it is needed. *If the roots are chilled*, **the plant may wilt or die.** Try this with two potted plants, as radish, coleus, tomato, etc. Put one pot in a dish of ice water, and the other in a dish of warm water, and keep them in a warm room. In a short time notice how stiff and vigorous is the one whose roots are warm, whereas the other may show signs of wilting.

150. **ROOTS EXCRETE.** — The plant not only absorbs what is already soluble, but *it is capable of* **rendering soluble** *small quantities of the insoluble substances present in the soil, and which may be needed for plant-food.* The plant accomplishes this result by means of substances excreted by the roots. These substances may even etch marble. On a polished marble block, place a half-inch of sawdust or soil, in which plant seeds. After the plants have attained a few leaves, turn the mass of sawdust over and observe the prints of the roots on the marble. These prints will be very faint. An illustration of this experiment is given on page 73. Carefully pull up a young seedling which is growing in soft soil, and notice how tenaciously the soil particles are held to the root (Fig. 110).



110. The rootlets and root-hairs cling to the particles of soil.

151. **THE FOOD MATERIALS.**—We have seen that *all food materials must be* **in solution in water** *in order to be taken in by the roots.* Different kinds of plants require different kinds and proportions of the food materials, but ordinary green plants are supposed to require at least eleven of the elementary substances in order to live. These are:

Carbon, C.
Oxygen, O.
Nitrogen, N.
Hydrogen, H.
Potassium, K.
Calcium, Ca.
Magnesium, Mg.
Phosphorus, P.
Sulfur, S.
Iron, Fe.
Chlorine, Cl. (in some plants).

All these elements must be in **combinations,** *not in their elemental form, in order to be absorbed by roots.*

152. *Usually all of these except carbon and oxygen are taken in* **only through the roots.** Some of the oxygen is taken in by the roots in the form of water (which is H_2O), and in other compounds. Some carbon is probably taken in by the roots in the form of carbonates, but it is doubtful whether this source of carbon is important to the plant. Water is not only a carrier of plant-food: it is itself a plant-food, for some of it is used in the building up of organic materials. The seven elements in the right-hand column are called the **mineral elements:** *they remain in the ash, when the plant is burned. The mineral elements come from the soil.*

153. **The ash is a small part of the total weight** *of the plant.* In a corn plant of the roasting-ear stage, the ash (what remains after ordinary burning) is about 1 per cent of the total substance.

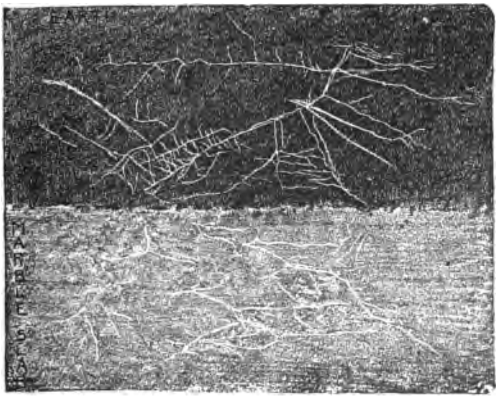
154. **Water is the most abundant single constituent or substance of plants.** In the corn plant of the roasting-

ear stage, about 80 per cent of the substance is water. A fresh turnip is over 90 per cent water. Fresh wood of the apple contains about 45 per cent of water. *The plant secures its water from the soil.*

Review.—What is plant-food? Where does some of it come from? Describe the feeding root. Describe root-hairs. What is their function? How does the root-hair differ from the rootlet? What is osmosis? Describe the experiment. How does the soil water get into the root-hair? For how long does this absorption continue? Under what conditions may the root-hair lose its sap? In what condition must the soil water be in order to be absorbed? What may result if the food solutions are too strong? Has this fact any interest to the plant-grower? What is root-pressure? How is the water held in the soil when it is most valuable to the plant? How are plants able to live in dry soil? Why do roots need air? How do they get it? Describe what effect a cold soil has on roots. How do roots secure the plant-food in the soil particles? What elements are necessary to plants? In what forms must these elements be in order to be absorbed by the roots? About what percentage of the whole substance is ash? What is the most abundant constituent in plants? Whence does it come?

Note.—Examine soil under a lens, to see the odd and miscellaneous particles of which it is composed.

Not all kinds of plants exhibit strong root-pressure. The grape vine is a good subject to show it. If pot plants are used, choose a well-rooted one with a straight stem. Coleus, begonia and Impatiens Sultani are good subjects. These can be had at greenhouses.



Root excretions may etch a marble surface.

CHAPTER XII

THE MAKING OF THE LIVING MATTER

155. **SOURCES OF FOOD.**—The ordinary green plant has but *two sources from which to obtain food*,—**the air and the soil.** When a plant is thoroughly dried in an oven, the water passes off: *this water came from the soil* (154). The remaining part is called the **dry substance** or **dry matter.** If the dry matter is burned in an ordinary fire, only the **ash** remains: *this ash came from the soil* (152). The part which passed off as gas in the burning *contained the elements which came from the air:* it also contained some of those which came from the soil—all those (as nitrogen, hydrogen, chlorine) which are transformed into gases by the heat of a common fire.

156. **CARBON.**—**Carbon enters abundantly into the composition of all plants.** Note what happens when a plant is burned without free access of air, or smothered, as in a charcoal pit. *A mass of charcoal remains, almost as large as the body of the plant.* Charcoal is almost pure *carbon*, the ash present being so small in proportion to the large amount of carbon that we look on the ash as an impurity. Half or more of the dry substance of a tree is carbon. When the tree is charred (or incompletely burned), the carbon remains in the form of charcoal. The carbon goes off as a gas when the plant is burned in air. It does not go off alone, but in combination with oxygen, and in the form called *carbon dioxid gas*, CO_2.

157. **The green plant secures its carbon from the air.** In other words, much of the solid matter of the plant comes from one of the gases. By volume *carbon dioxid*

forms only about three-hundredths of 1 per cent of the air. It would be very disastrous to animal life, however, if this percentage were much increased, for it excludes the life-giving oxygen. Carbon dioxid is often called "foul-gas." It may accumulate in old wells, and an experienced person will not descend into such wells until they have been tested with a torch. If the air in the well will not support combustion, that is, if the torch is extinguished, it usually means that carbon dioxid has drained into the place. The air of a closed school-room often contains far too much of this gas along with little solid particles of waste matters. Carbon dioxid is often known as carbonic acid gas.

158. **APPROPRIATION OF THE CARBON.**—*The carbon dioxid of the air readily* **diffuses into the leaves and other green parts of the plant.** The leaf is delicate in texture, and often the air can enter directly into the leaf tissues. There are, however, special inlets provided for the admission of gases into the leaves and other green parts. These inlets consist of *numerous pores* (stomates or stomata), *which are especially abundant on the under surface of the leaf.* The apple leaf contains about one hundred thousand of these pores to each square inch of the under surface. Through these breathing pores the outside air enters into the air-spaces of the plant, and finally into the little cells containing the living matter. In Part III these breathing pores will be studied.

159. **CHLOROPHYLL.**—*The green color of leaves is due to a substance called* **chlorophyll.** Purchase at the drug store about a gill of wood alcohol. Secure a leaf of geranium, clover, or other plant which has been exposed to sunlight for a few hours and, after dipping it for a minute in boiling water, put it in a white cup with sufficient alcohol to cover the leaf. Place the cup on the stove where it is not hot enough for the alcohol to take fire. After a time the chlorophyll is dissolved by the alcohol,

which has become an intense green. Save this leaf for a future experiment. *Without chlorophyll, the plant can not appropriate the carbon dioxid of the air.*

160. In most plants this chlorophyll or leaf-green is scattered throughout the green tissues in little oval bodies, and *these bodies are most abundant near the upper surface of the leaf, where they can secure the greatest amount of light.* Without this green coloring matter, there would be no reason for the large flat surfaces which the leaves possess, and no reason for the fact that the leaves are borne most abundantly at the ends of branches, where the light is most available. Plants with colored leaves, as coleus, have chlorophyll, but it is masked by other coloring matter. This other coloring matter is usually soluble in hot water: boil a coleus leaf and notice that it becomes green and the water becomes colored.

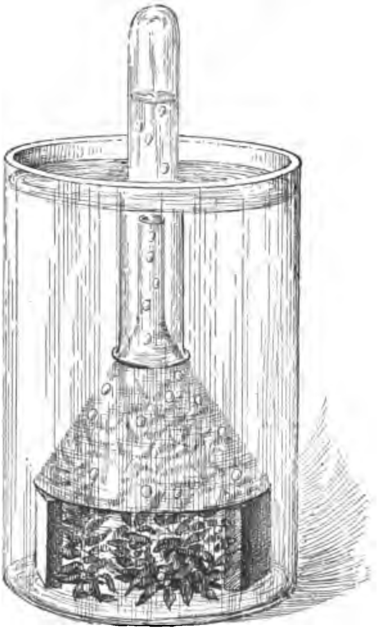
161. *Plants grown in* **darkness are yellow and slender,** *and do not reach maturity.* Compare the potato sprouts which have grown from a tuber lying in the dark cellar with those which have grown normally in the bright light (Fig. 42). The shoots have reached out for that which they cannot find; and when the food which is stored in the tuber is exhausted, these shoots will have lived useless lives. A plant which has been grown in darkness from the seed will soon die, although for a time the little seedling will grow very tall and slender. *Light favors the production of chlorophyll.* Sometimes chlorophyll is found in buds and seeds, but it is probable that these places are not perfectly dark. Notice how potato tubers develop chlorophyll, or become green, when exposed to light.

162. **PHOTOSYNTHESIS.—Carbon dioxid is absorbed by the leaf during sunlight, and oxygen is given off.** We have seen (157) that carbon dioxid will not support animal life. Experiments have shown that *carbon dioxid is absorbed and that oxygen is given off by all green surfaces*

of plants during the hours of sunlight. How the carbon dioxid which is thus absorbed may be used as food is a complex question, and need not be studied here.

163. *Chlorophyll absorbs the energy of the sun's rays, and the energy thus obtained is used by the living matter in uniting the carbon dioxid absorbed from the air with some of the water brought up by the roots. The process by which these compounds are united is a complex one, but the ultimate result usually is starch.* No one knows all the details of this process; and our first definite knowledge of the product begins when starch is deposited in the leaves. The process of using the carbon dioxid of the air has been known as carbon-assimilation, but the term now most used is **photosynthesis** (from Greek words, meaning *light* and *to put together*).

164. **STARCH.**—*All starch is composed of carbon, hydrogen, and oxygen* ($C_6H_{10}O_5$). The sugars and the woody substances are very similar to it in composition. All these substances are called **carbohydrates.** In making this starch from the carbon and oxygen of carbon dioxid and from the hydrogen and oxygen of the water, *there is a surplus of oxygen.* It is this oxygen which is given off into the air. To test the giving off of oxygen by day, make the experiment illustrated in Fig. 111. Under a funnel in a



111. To show the escape of oxygen.

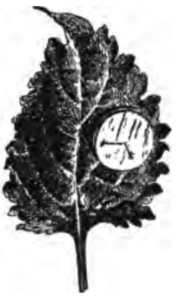
deep glass jar containing fresh spring or stream water, place fresh pieces of the common water-weed elodea (or anacharis). Invert a test tube over the stem of the funnel. In sunlight bubbles of oxygen will arise and collect in the test tube. When a sufficient quantity of oxygen has collected, a lighted taper inserted in the tube will glow with a brighter flame, showing the presence of oxygen. A simpler but less accurate experiment is to immerse an active leaf of a water plant, and to observe the bubbles which arise. From a leaf in sunlight the bubbles often arise in great numbers; but from one in shadow, the bubbles usually are comparatively few. Fig. 112. Some of the bubbles may be only air, particularly if marked changes in temperature occur. Observe the bubbles on pond scum and water weeds on a bright day.

112. To show that a leaf may give off oxygen.

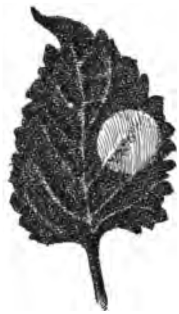
165. *Starch is present in the green leaves of plants which have been exposed to sunlight; but* **in the dark no starch can be formed from carbon dioxid.** Apply iodine to the leaf from which the chlorophyll was dissolved in a previous experiment (159). Note that the leaf is colored purplish brown throughout. The leaf contains starch (75). Secure a leaf from a plant which has been in the darkness for about two days. Dissolve the chlorophyll as before, and attempt to stain this leaf with iodine. No purplish brown color is produced.

166. *The starch manufactured in the leaf may be entirely* **removed during darkness.** Secure a plant which has been kept in darkness for twenty-four hours or more. Split a small cork and pin the two halves on opposite sides of one of the leaves, as shown in Fig. 113. Place the plant

in the sunlight again. After a morning of bright sunshine dissolve the chlorophyll in this leaf with alcohol; then stain the leaf with the iodine. Notice that the leaf is stained deeply in all parts except in that part over which the cork was placed, as in Fig. 114. *There is no starch in the covered area.*



113. Excluding light from part of a leaf.



114. The result.

167. *Plants or parts of plants which have developed no chlorophyll* **can form no starch.** Secure a variegated leaf of coleus, ribbon grass, geranium, or of any plant showing both white and green areas. On a day of bright sunshine test one of these leaves by the alcohol and iodine method for the presence of starch. Observe that the parts devoid of green color have formed no starch. However, after starch has once been formed in the leaves, it may be changed into soluble substances and removed to be again converted into starch in other parts of the living tissues.

168. **DIGESTION.**—*Starch is in the form of insoluble granules. Whenever the material is carried from one part of the plant to another for purposes of growth or storage, it is made soluble before it can be transported.* When this starchy material is transferred from place to place, it is usually changed into sugar by the action of a ferment. *This is a process of* **digestion.** It is much like the change of starchy foods to sugary foods by the saliva.

169. **DISTRIBUTION OF THE DIGESTED FOOD.**—After being changed to the soluble form, *this material is ready to be used in growth*, either in the leaf, in the stem, or in the roots. With other more complex products it is then dis-

tributed throughout all of the growing parts of the plant; and when passing down to the root it seems to pass more readily through the *inner bark*, in plants which have a definite bark. This gradual downward diffusion of materials suitable for growth through the inner bark is the process referred to when the "descent of sap" is mentioned. Starch and other products are often stored in one growing season to be used in the next season (Chapter VI). If a tree is constricted or strangled by a wire around its trunk, the digested food cannot readily pass down and it is stored above the girdle, causing an enlargement.

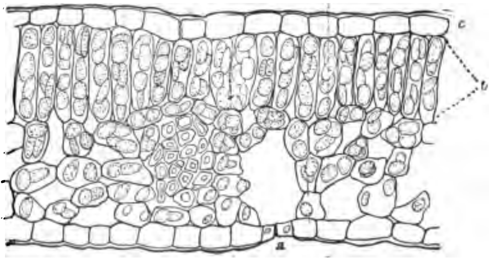
170. **ASSIMILATION.**—*The food from the air and that from the soil* **unite in the living tissues** (see photosynthesis, 162, 163). The sap that passes upwards from the roots in the growing season is made up largely of the soil-water and the salts which have been absorbed in the diluted solutions. This upward-moving water is conducted largely through certain tubular cells of the *young wood*. These cells are never continuous tubes from root to leaf; but the water passes readily from one cell to another in its upward course.

171. The upward-moving water gradually passes to the growing parts, and everywhere in the living tissues, particularly in the leaves, *it meets the products of assimilation from the leafy parts*. Under the influence of the living matter of the plant, this product from the leaves first forms combinations with *the nitrogen*. A substance more complex than sugar is then formed, and gradually *compounds are formed which contain sulfur, phosphorus, potassium, and other elements, until finally protoplasm is manufactured.* **Protoplasm** *is the living matter in plants.* It is in the cells, and is usually semi-fluid. Starch is not living matter. The complex process of building up the protoplasm is called **assimilation.**

172. **RESPIRATION.— Plants need oxygen for respiration** *just as animals do.* We have seen that plants need the

carbon dioxid of the air. To most plants the nitrogen of the air is inert, and serves only to dilute the other elements; but the *oxygen is necessary for all life.* We know that all animals need this oxygen in order to breathe or respire. In fact, they have become accustomed to it in just the proportions found in the air; and this is now best for them. When animals breathe the air once they make it foul, because they use some of the oxygen and give off carbon dioxid. Likewise, *all living parts of the plant must have a constant supply of oxygen.* Roots also need it (148).

173. The oxygen passes into the air-spaces and into the protoplasm, entering into combinations the final products of which are *carbon dioxid and water.* The air-spaces are equal in bulk to the tissues (Fig. 115). As a result of the use of this oxygen alone at night, plants give off carbon dioxid as animals do. **Plants respire;** *but since they are stationary, and more or less inactive, they do not need as much oxygen as animals, and they do not give off so much carbon dioxid.* During the day plants use so much more carbon dioxid than oxygen that they are said to purify the air. The carbon dioxid which plants give off at night is very slight in comparison with that given off by animals; so that a few plants in a sleeping room need not disturb one more than a family of mice. Plants usually grow most rapidly in darkness.



115. Section of a leaf, showing the air-spaces. Breathing pore or stoma at *a*. The palisade cells which chiefly contain the chlorophyll are at *b*. Epidermal cells at *c*.

174. **TRANSPIRATION.**—We have found that the plant takes its food from the soil in very dilute solutions.

Much more water is absorbed by the roots than is used in growth, *and this surplus water is given off from the leaves into the atmosphere by an evaporation process known as* **transpiration.** The transpiration takes place more abundantly from the under surfaces of leaves, and through the pores or stomates. It has been found that a sunflower plant of the height of a man, during an active period of growth, gives off more than a quart of water per day. A large oak tree may transpire 150 gallons per day during the summer. For every ounce of dry matter produced, it is estimated that from fifteen to twenty-five pounds of water must pass through the plant. Cut off a succulent shoot of any plant, stick the end of it through a hole in a cork and stand it in a small bottle of water. Invert over this bottle a large-mouthed bottle (as a fruit-jar), and notice that a

116. To illustrate transpiration.

mist soon accumulates on the inside of the glass. In time drops of water form. The experiment may be varied as shown in Fig. 116. Or invert the fruit-jar over an entire plant, as shown in Fig. 117, taking care to cover the soil with oiled paper or rubber cloth to prevent evaporation from the soil. Even in winter moisture is given off by leafless twigs. Cut a twig, seal the severed end with wax, and allow the twig to lie several days: it shrivels. *There must be some upward movement of water even in winter, else plants would shrivel and die.*

117. To illustrate transpiration.

175. *When the roots fail to supply to the plant sufficient water to equalize that transpired by the leaves*, **the plant wilts.** Transpiration from the leaves and delicate shoots is increased by all of the conditions which would increase evaporation, such as higher temperature, dry air or wind. The breathing pores are so constructed that they open and close with the varying conditions of the atmosphere, and thereby regulate transpiration. However, during periods of drought or of very hot weather, and especially during a hot wind, the closing of these stomates cannot sufficiently prevent evaporation. The roots may be very active and yet fail to absorb sufficient moisture to equalize that given off by the leaves. The plant wilts. Any injury to the roots or even chilling them (149) may cause the plant to wilt. On a hot, dry day note how the leaves of corn "roll" towards afternoon. Early the following morning note how fresh and vigorous the same leaves appear. Water is also forced up by root-pressure (146). Some of the dew on the grass in the morning

may be the water forced up by the roots; some of it is the condensed vapor of the air.

176. *The wilting of a plant is due to the* **loss of water from the cells.** The cell walls are soft, and collapse. A toy balloon will not stand alone until it is inflated with air or liquid. In the woody parts of the plant the cell walls may be stiff enough to support themselves, even though the cell is empty. Measure the contraction due to wilting and drying by tracing a fresh leaf, and then tracing the same leaf after it has been dried between papers. The softer the leaf, the greater will be the contraction.

REVIEW.—Whence comes the food of plants? What is meant by the dry substance? What is charcoal? How is it obtained? How much of the dry substance is carbon? What becomes of it when the plant is burned in air? Whence comes the carbon? What is carbon dioxid? How abundant is it in the air? How does the CO_2 get into the leaf? What is chlorophyll? What function has it? Where are the chlorophyll bodies located? What relation has light to chlorophyll? When is CO_2 absorbed? What is formed after CO_2 is taken in? Define photosynthesis. What is starch? What is given off when starch is made by photosynthesis? In what part of the plant is starch first made? When? What are carbohydrates? What is digestion of starch? How is the digested food distributed? Explain assimilation. What is the product of assimilation? Explain respiration. When are O and CO_2 given off? Define transpiration. Why do plants wilt?

An egg-shell farm for the pupil's desk.

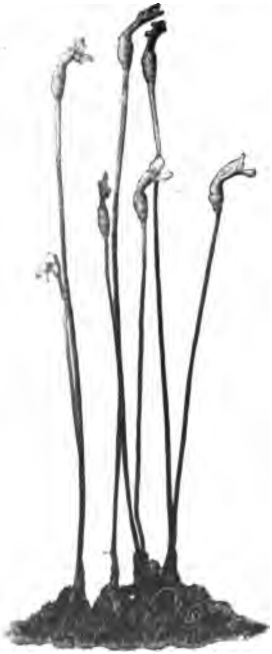
CHAPTER XIII

DEPENDENT PLANTS

177. **DEPENDENT AND INDEPENDENT PLANTS.**— Plants with roots and foliage usually depend on themselves. They collect the raw materials and make them over into assimilable food. They are **independent.** Plants without green foliage cannot make food: they must have it made for them or they die. They are **dependent.** The potato sprout (Fig. 42) cannot collect and elaborate carbon dioxid. It lives on the food stored in the tuber.

178. *All plants with naturally white or blanched parts are dependent.* Their leaves do not develop. They live on organic matter — that which has been made by a plant or an animal. The Indian pipe, aphyllon (Fig. 118), beech drop, coral root (Fig. 119) among flower-producing plants, also mushrooms and other fungi (Figs. 120, 121) are examples.

179. **PARASITES AND SAPROPHYTES** —A plant which is dependent on a living plant or animal is a **parasite,** and the plant or animal on which it lives is the **host.** The dodder is a true parasite. So are the rusts and mildews which attack leaves and shoots and injure them.

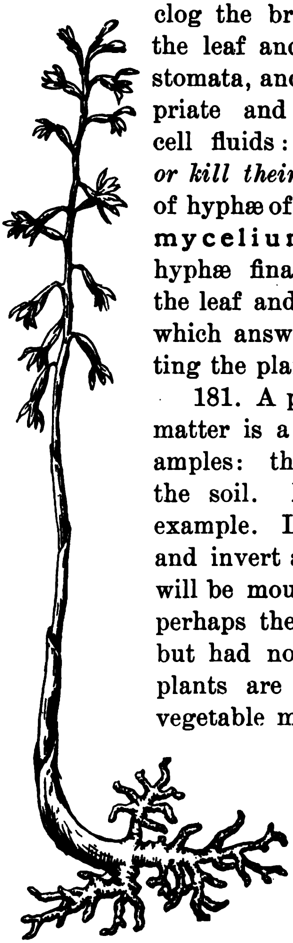


118. A parasite, growing in woods.— Aphyllon. It is in bloom.

180. The threads of the parasitic fungus usually creep through the intercellular spaces in the leaf or stem and send suckers (or haustoria) into the cells (Fig. 122). These threads (or hyphæ) clog the breathing spaces of the leaf and often plug the stomata, and they also appropriate and disorganize the cell fluids: *thus they injure or kill their host.* The mass of hyphæ of a fungus is called **mycelium.** Some of the hyphæ finally grow out of the leaf and produce spores or reproductive cells which answer the purpose of seeds in distributing the plant (b, Fig. 122).

120. A mushroom, example of a saprophytic plant.

181. A plant which lives on dead or decaying matter is a **saprophyte.** Mushrooms are examples: they live on the decaying matter in the soil. Mould on bread and cheese is an example. Lay a piece of moist bread on a plate and invert a tumbler over it. In a few days it will be mouldy. The spores were in the air, or perhaps they had already fallen on the bread but had not opportunity to grow. Most plants are able to make use of the humus or vegetable mould in the soil, and to that extent might be called saprophytic.


119. Corallorhiza or coral-root, showing the mycorrhizas.

182. Some parasites spring from the ground (Figs. 118, 119), as other plants do, but they are parasitic *on the roots of their hosts.* Some parasites may be partially parasitic and partially saprophytic. Many (perhaps most) of these root-

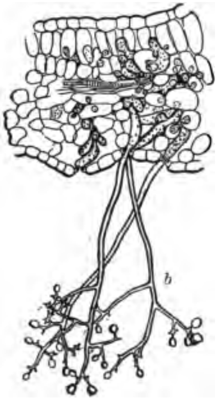
parasites are aided in securing their food by soil fungi, which spread their delicate threads over the root-like branches of the parasite and act as intermediaries between the food and the parasite. The roots of the coral-root (Fig. 119) are covered with this fungus, and the roots have practically lost the power of absorbing food direct. These fungous-covered roots are known as **mycorrhizas** (meaning "fungus root"). Mycorrhizas are not peculiar to parasites. They are found on many wholly independent plants as, for example, the heaths, oaks, apples, and pines. It is probable that the fungous threads perform some of the offices of root-hairs to the host. On the other hand, the fungus obtains some nourishment from the host. The association seems to be mutual.

183. Saprophytes break down or decompose organic substances. Chief of these saprophytes are the microscopic organisms known as **bacteria** (Fig. 123). These innumerable bodies are immersed in water or in animal and plant juices, and absorb food over their entire surface. By breaking down organic combinations, *they produce decay*. Largely through their agency, and that of many true but microscopic fungi, *all things pass into soil and gas*. Thus are the bodies of plants and animals removed and the continuing round of life is maintained.

121. Saprophytic fungus. One of the shelf fungi (Polyporus) growing on dead trunks and logs.

184. *Some parasites are green-leaved.* Such is the mistletoe. They anchor themselves on the host and

absorb its juices, but they also appropriate and use the carbon dioxid of the air. In some groups of colored bacteria the process of photosynthesis, or something equivalent to it, takes place.



122. A parasitic fungus, magnified. The mycelium, or vegetative part, is shown by the dotted-shaded parts ramifying in the leaf tissue. The rounded haustoria projecting into the cells, are also shown. The long fruiting parts of the fungus hang from the under surface of the leaf.

185. Parasitism and saprophytism are usually regarded as degeneration, that is, as a **loss of independence.** The ancestors of these plants might have been independent. Thus, the whole class of fungi is looked upon as a degenerate evolution. *The more a plant depends on other plants, the more it tends still further to lose its independence.*

186. **EPIPHYTES.** — To be distinguished from the dependent plants are those which grow on other plants without taking food from them. These are green-leaved plants whose roots burrow in the bark of the host plant and perhaps derive some food from it, but which subsist chiefly on materials which they secure from air-dust, rain-water and the air. These plants are **epiphytes** (meaning "upon plants") or air-plants.

187. Epiphytes abound in the tropics. Orchids are amongst the best known examples (Fig. 13). The Spanish moss or tillandsia of the South is another. Mosses and lichens which grow on trees and fences may also be called epiphytes. In the struggle for existence, the plants probably *have been driven to these special places* in which to find opportunity to grow. Plants grow where they must, not where they will.

123. Bacteria, much magnified.

Review.—What is an independent plant? Dependent? Give examples. How are dependent plants distinguished from others in looks? Define parasite. Saprophyte. Give examples. What is a host? How does a parasitic fungus live on its host? What are hyphæ? What is mycelium? What are root-parasites? Give examples. What is a mycorrhiza? What is the relation of the soil fungus to its host? What is the role or office of saprophytes in nature? Are parasites ever green? Explain. What has probably been the evolution of most parasites and saprophytes? What is an epiphyte? Give examples. How do they live? Why may they have become epiphytes?

Note.—Usually, the most available parasite is the dodder. It is common in swales from July until autumn, winding its coral-yellow stems about herbs and soft-growing bushes. It is a degraded member of the morning-glory family. It produces true flowers and seeds. These seeds germinate the following spring. The slender young vine grows from the ground for a time, but if it fails to find a host, it perishes.

The cultivated mushroom, a saprophytic plant.

CHAPTER XIV

LEAVES AND FOLIAGE

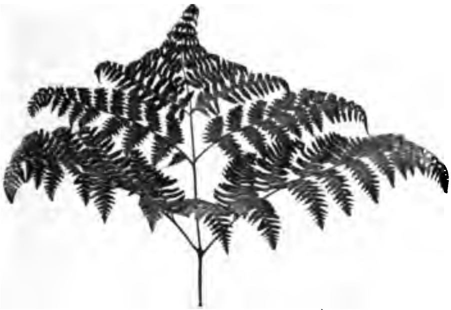
188. Leaves may be studied from two points of view —with reference to their **function,** or what they do; and with reference to their **form,** or their shapes and kinds.

189. **FUNCTION.**—Leaves, as we have seen, **make organic matters** from carbon dioxid and water; they **respire,** throwing off carbon dioxid as waste; they **digest** the starch, that it may be transported; and they perform other vital activities. Functions which require both lungs and stomach in animals (respiration and digestion) are performed by leaves; and in addition to these functions, they appropriate the carbon of the air (process of photosynthesis), a work which is peculiar to plants. Any part of the plant, however, may bear chlorophyll and perform the functions of leaves. Even aërial roots, as of orchids, are sometimes green.

124. Simple leaf. One of the eupatoriums or bonesets.

190. The general form and structure of leaves is intimately associated with their function: they are thin and much-expanded bodies, thereby exposing the **greatest possible surface to light and air.** The position of the leaves usually has relation to light, as we have seen (Chapter VIII). Leaves usually hang in such a way that one casts the least shade on the other; those die and fall which have the least favorable positions.

191. **FORM.**—Leaves are **simple** or unbranched (Fig. 124), and **compound** or branched (Fig. 125). The method of compounding or branching follows the style of veining. The veining, or **venation**, is of two general kinds: in most plants the main veins diverge, and there is a conspicuous network of smaller veins: such leaves are **netted-veined.** In other plants the main veins are parallel, or nearly so, and there is no conspicuous network: these are **parallel-veined** leaves (Fig. 136). The venation of netted-veined leaves is pinnate or feather-like, when the veins arise from the side of a continuous midrib (Fig. 124); palmate or digitate (hand-like), when the veins arise from the apex of the midrib (Fig. 126). If the leaf were divided between the main veins, it would be pinnately or digitately compound.



125. Compound or branched leaf of brake (which is a fern).

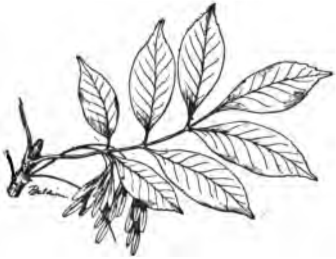
192. It is customary to speak of a leaf as compound only when the parts or branches are completely separate blades, as when the division extends to the midrib (Figs. 125, 127, 128). The parts or branches are known as **leaflets.** Sometimes the leaflets themselves are compound, and the whole leaf is then said to be *bi-compound* or *twice-compound* (Fig. 125). Some leaves are three-compound, four-compound, or five-compound. *Decompound* is a

126. Digitate-veined peltate leaf of nasturtium.

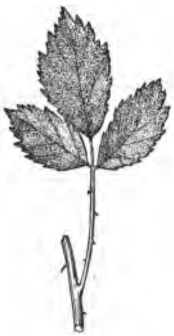
general term to express any degree of compounding beyond twice-compound.

193. Leaves which are not divided to the midrib are said to be:

- **lobed,** openings or sinuses not more than half the depth of the blade (Fig. 129).
- **cleft,** sinuses deeper than the middle.
- **parted,** sinuses two-thirds or more to the midrib (Fig. 130).
- **divided,** sinuses nearly or quite to the midrib.

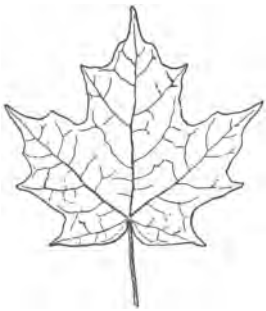

127. Pinnately compound leaf of ash.

The parts are called *lobes*, *divisions*, or *segments*, rather than leaflets. The leaf may be pinnately or digitately lobed, parted, cleft, or divided. A pinnately parted or cleft leaf is sometimes said to be **pinnatifid.**


128. Digitately compound leaf of raspberry.

194. Leaves may have one or all of three parts—**blade** or expanded part, **petiole** or stalk, **stipules** or appendages at the base of the petiole. All these parts are shown in Fig. 131. A leaf which has all three of these parts is said to be **complete.** The stipules are often green and leaf-like and perform the function of foliage, as in the pea and Japanese quince (the latter common in yards).

195. Leaves and leaflets which have no stalks are said to be **sessile** (Fig. 137), i. e., sitting. The


129. Lobed leaf of sugar maple.

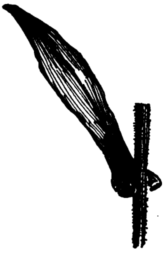
same is said of flowers and fruits. The blade of a sessile leaf may partly or wholly surround the stem, when it is said to be **clasping** (Fig. 132). In some cases the leaf runs down the stem, forming a wing: such leaves are said to be **decurrent** (Fig. 133). When opposite sessile leaves are joined by their bases, they are said to be **connate** (Fig. 134).

130. Digitately parted leaves of begonia.

196. Leaflets may have one or all of these three parts, but the stalks of leaflets are called **petiolules** and the stipules of leaflets are called **stipels**. The leaf of the garden bean has leaflets, petiolules, and stipels.

197. The blade is usually attached to the petiole by **its lower edge.** In pinnate-veined leaves, the petiole seems to continue through the leaf as a **midrib** (Fig. 124). In some plants, however, the petiole joins the blade inside or beyond the margin (Figs. 126, 135). Such leaves are said to be **peltate** or shield-shaped. This mode of attachment is particularly common in floating leaves (e. g., the water lilies). Peltate leaves are usually digitate-veined.

131. Complete leaves of willow.



132. Clasping leaf of wild aster.

198. **SHAPE.**—Leaves and leaflets are infinitely variable in shape. Names have been given to some of the more definite or regular shapes. These names are a part of the language of botany. These names represent ideal or typi-

cal shapes, but there are no two leaves alike and very few which perfectly conform to the definitions. The shapes are likened to those of familiar objects or of geometrical figures. Some of the commoner shapes are as follows:

Linear, several times longer than broad, with the sides nearly or quite parallel. Spruces and most grasses are examples. Fig. 136. In linear leaves, the main veins are usually parallel to the midrib.

Oblong, twice or thrice as long as broad, with the sides parallel for most of their length. Fig. 137 shows the short-oblong leaves of the box, a plant which is much used for edgings in gardens.

Elliptic differs from the oblong in having the sides gradually tapering to either end from the middle. The European beech, Fig. 138, has elliptic leaves. (This tree is often planted.)

Lanceolate, four to six times longer than broad, widest below the middle and tapering to each end. Some of the narrow-leaved willows are examples. Most of the willows and the peach have oblong-lanceolate leaves.

Spatulate, a narrow leaf which is broadest towards the apex. The top is usually rounded. It is much like an oblong leaf.

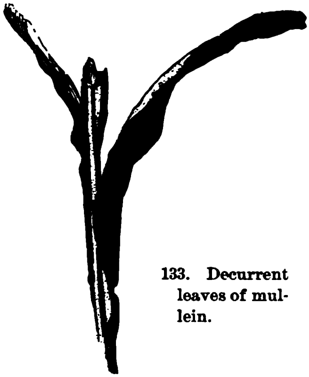
Ovate, shaped somewhat like the longitudinal section of an egg: twice as long as broad, tapering from near the base to the apex. This is one of the commonest leaf forms. Fig. 139.

Obovate, ovate inverted,—the wide part towards the apex. Leaflets of horse-chestnut are obovate. This form is commonest in leaflets of digitate leaves.

Reniform, kidney-shaped. This form is sometimes seen in wild plants, particularly in root-leaves. Leaves of wild ginger are nearly reniform.

Orbicular, circular in general outline. Very few leaves are perfectly circular, but there are many which are nearer circular than any other shape. Fig. 140.

The shape of many leaves is described in combinations of these terms, as ovate-lanceolate, lanceolate-oblong.

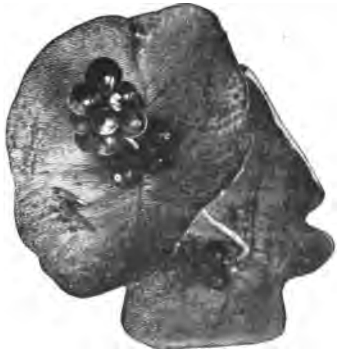


133. Decurrent leaves of mullein.

199. The shape of the base and apex of the leaf or leaflet is often characteristic. The base may be **rounded** (Fig. 124), **tapering** (Fig. 127), **cordate** or heart-shaped (Fig. 139), **truncate** or squared as if cut off. The apex may be blunt or **obtuse, acute** or sharp, **acuminate** or long-pointed, **truncate** (Fig. 141).

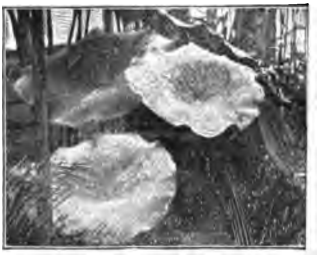
200 The shape of the margin is also characteristic of each kind of leaf. The margin is **entire** when it is not indented or cut in any way (Fig. 137). When not entire, it may be **undulate** or wavy (Fig. 126), **serrate** or saw-toothed (Fig. 139), **dentate** or more coarsely notched (Fig. 124), **crenate** or round-toothed, **lobed**, etc.

201. Leaves often differ greatly in form on the same plant. Observe the different shapes of leaves on the young growths of mulberries and wild grapes; also on vigorous squash and pumpkin vines. In some cases there may be simple and compound leaves on the same plant. This is marked in the so-called Boston ivy or ampelopsis (Fig. 142), a vine which is used to cover brick and stone buildings. Different degrees of compounding, even in the same leaf, may often be found in honey locust and



134. Two pairs of connate leaves of honeysuckle.

Kentucky coffee tree. Remarkable differences in forms are seen by comparing seed-leaves with mature leaves of any plant (Fig. 143).



135. Peltate leaves of so-called Egyptian lotus.

136. Linear-acuminate leaf of grass.

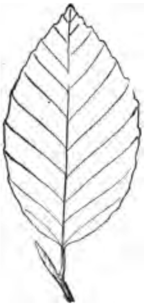
202. **THE LEAF AND ITS ENVIRONMENT.** — The form and shape of the leaf often have direct relation to the **place in which the leaf grows.** *Floating leaves are usually expanded and flat*, and the petiole varies in length with the depth of the water. *Submerged leaves are usually linear or thread-like*, or are cut into very narrow divisions. Thereby is more surface exposed, and possibly the leaves are less injured by moving water.

203. The largest leaves on a sun-loving plant are usually those which are *fully exposed to light*. Compare the sizes of the leaves on the ends of branches with those at the base of the branches or in the interior of the tree-top. In dense foliage masses, the petioles of the lowermost or undermost leaves tend to **elongate** — to push the leaf to the light (Fig. 144).

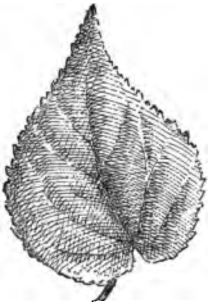
137. Short-oblong leaves of box.

204. On the approach of winter the leaf ceases to work, and often dies. It may drop, when it is said to be **deciduous**; or it may remain on the plant, when it is said to be **persistent.** If persistent leaves remain green during the winter, the plant is said to be

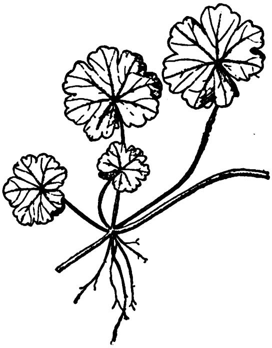
evergreen. Most leaves fall by breaking off at the lower end of the petiole with a *distinct joint or articulation.* There are many leaves, however, which wither and hang on the plant until torn off by the wind: of such are the leaves of grasses, sedges, lilies, orchids, and other plants known as monocotyledons (Chap. XXIII). Most leaves of this character are parallel-veined. Consult 439.



138. Elliptic leaf of purple beech.

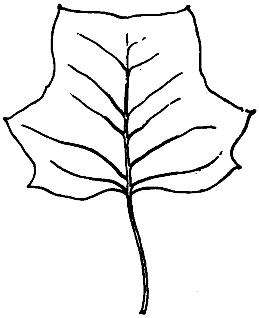


139. Ovate serrate leaf of hibiscus.



140. Orbicular lobed leaves.

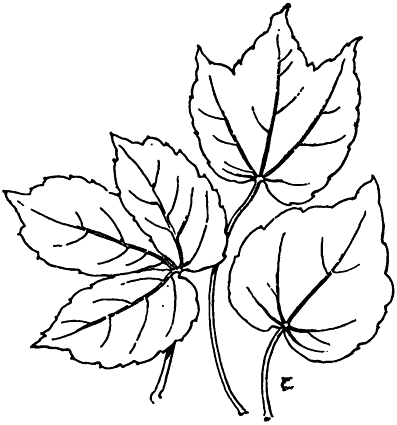
205. *Leaves also die and fall* **from lack of light.** Observe the yellow and weak leaves in a dense tree-top or in any thicket. Why do the lower leaves die on house-plants? Note the carpet of needles under the pines. All evergreens shed their leaves after a time. Counting back from the tip of a pine or spruce shoot, determine how many years the leaves persist (Fig. 145). In some spruces a few leaves may be found on branches ten or more years old. Leaves usually persist longest in the lightest positions (Fig. 77).



141. Truncate leaf of tulip-tree.

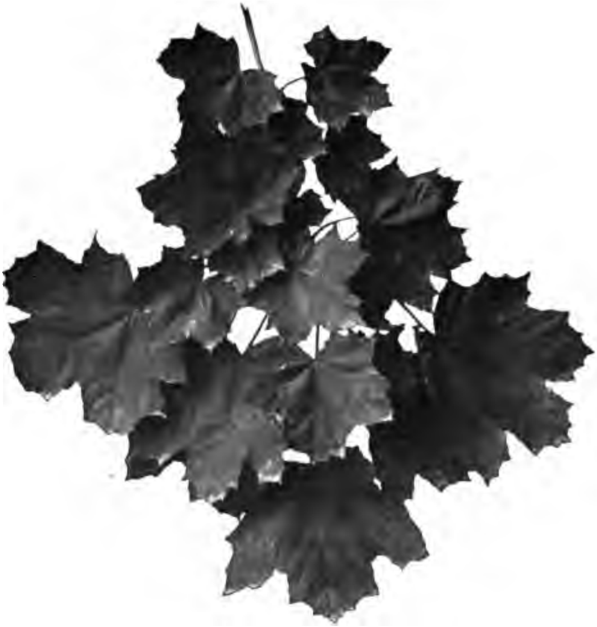
206. Although the forms and positions of leaves often have direct relation to the places and conditions in which

the leaves grow, *it is not known that all forms and shapes have been developed to adapt the plant to its environment.* It is probable that the toothing or lobing of the leaf-margins is due to the same causes which produce compounding or branching of leaves, but what these causes are is not known. It has been suggested that leaves have become compound in order to increase their surface and thereby to offer a greater exposure to light in shady places, but very many sun-loving species have compound leaves, and many shade-loving species have simple and even small leaves. Again, it has been suggested that compound leaves shade underlying leaves less than simple leaves do.

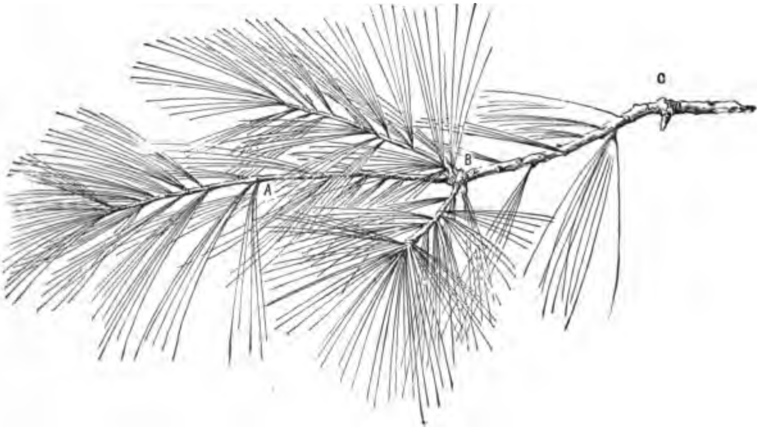

142. Different forms of leaves from one plant of ampelopsis.

207. **HOW TO TELL A LEAF.**—It is often difficult to distinguish compound leaves from leafy branches and leaflets from leaves. As a rule, leaves can be told by the following tests: (1) Leaves are **temporary structures,** sooner or later falling. (2) Usually **buds are borne in their axils.** (3) Leaves are usually **borne at joints or nodes.** (4) They arise on wood of the **current-year's growth.** (5) They have a more or less **definite arrangement.** When leaves fall, the twig which bore them remains; when leaflets fall, the main petiole which bore them falls also.

143. Muskmelon seedlings, with the unlike seed-leaves and true leaves.

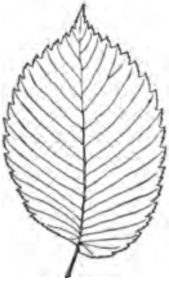


144. A leaf mosaic of Norway maple. Note the varying lengths of petioles.



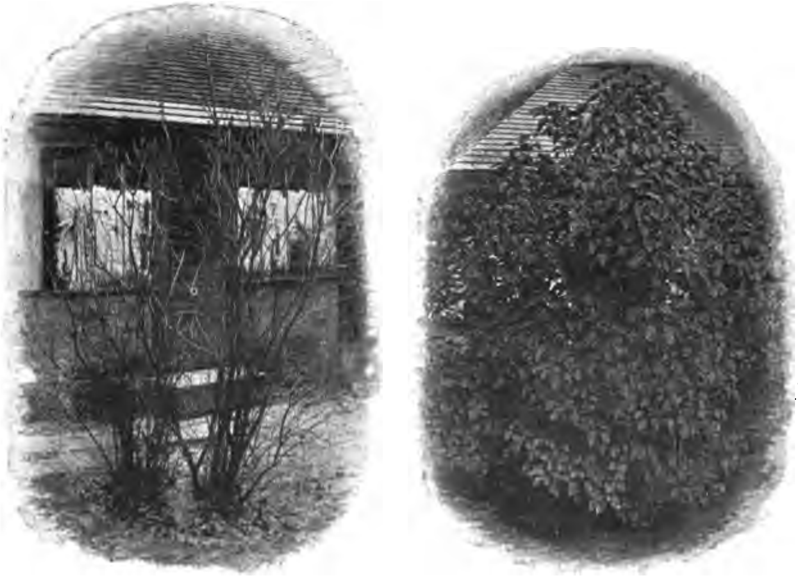
145. Shoot of the common white pine, one-third natural size.

The picture shows the falling of the leaves from the different years growth. The part of the branch between the tip and A is the last season's growth; between A and B it is two years old; the part between B and C is three years old; it has few leaves. The part that grew four seasons ago—beyond C—has no leaves.



146. Oblique leaf of the elm.

Review.—How may leaves be studied? What is meant by function? What do leaves do? What other parts may perform the function of leaves? How is form of leaves associated with their function? What are simple leaves? Compound? What is venation? What are the types or kinds of venation? What are the two types of compound leaves? What is a leaflet? Define bicompound; decompound. What are lobed, cleft, parted, and divided leaves? Pinnatifid leaf? Complete leaf? Complete leaflet? What is a sessile leaf? How may the petiole join the blade? How are the shapes of leaves named or classified? Define the shapes described in 198. Describe common shapes of the base of the leaf. Of the apex. Of the margin. How are the forms and sizes of leaves ever related to the place in which they grow? Why do leaves fall? Define deciduous. Persistent. Evergreen. When do pine leaves fall? How can you distinguish leaves? Describe the leaf in Fig. 146.



The same lilac bushes in January and July.—Framework and foliage.

CHAPTER XV

MORPHOLOGY, OR THE STUDY OF THE FORMS OF PLANT MEMBERS

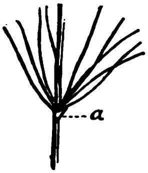
208. Botanists interpret all parts of the plant in terms of root, stem, and leaf. That is, the various parts, as thorns, flowers, fruits, bud-scales, tendrils, and abnormal or unusual members, are supposed **to represent or to stand in the place of roots, stems (branches), or leaves.**

209. The forms of the parts of plants are interesting, therefore, in three ways: (1) merely as **forms**, which may be named and described; (2) their relation to **function**, or how they enable the part better to live and work; (3) their **origin**, as to how they came to be and whether they have been produced by the transformation of other parts. The whole study of forms is known as **morphology** (literally, the "science of forms"). We may consider examples in the study of morphology.

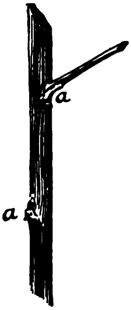
210. It is customary to say that the various parts of plants are *transformed* or *modified* root, stem, or leaf, but the words transformation and modification are not used in the literal sense. It is meant that the given part, as a **tendril**, may **occupy the place of or represent** a leaf. It was not first a leaf and then a tendril: the part develops into a tendril instead of into a leaf: it stands where a leaf normally might have stood: it is the historical descendant of the leaf.

211. It is better to say that parts which have similar origins, which arise from the same fundamental type, or which are of close genealogical relationship, are **homologous.** Thus the tendril, in the instance assumed above, is homologous with a leaf. Parts which have similar func-

tions or perform similar labor, without respect to origins, are **analogous.** Thus a leaf-tendril is analogous to a branch-tendril, but the two are not homologous.



147. Leaf and cladophylla of asparagus.



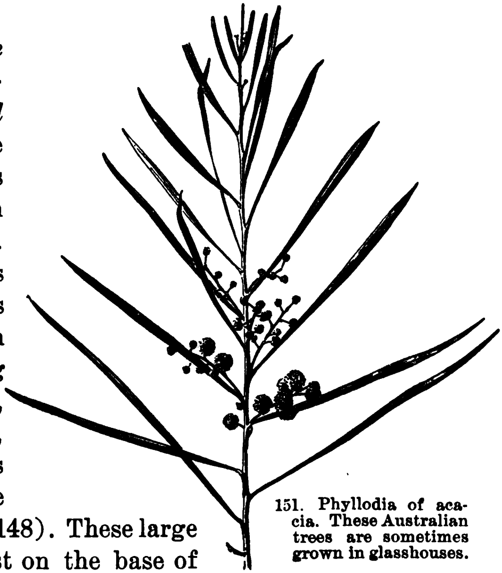
148. Leaves of asparagus.

212. There are five tests by means of which we may hope to determine what a given part is: (1) by the **appearance** or **looks** of the part (the least reliable test); (2) by the **position** of the part with relation to other parts — its place on the plant; (3) by **comparison** with similar parts on other plants (comparative morphology); (4) by study of **intermediate** or **connecting** parts; (5) by study of the **development** of the part in the bud or as it originates, by means of the microscope (embryology). The last test can be applied only by the trained investigator, but it often gives the most conclusive evidence. Even with the application of all these tests, it is sometimes impossible to arrive at a definite conclusion as to the origin or morphology of a part. For example, it is not yet agreed whether most cactus spines represent leaves or

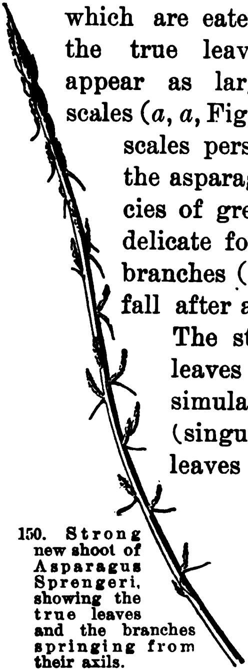
149. Fern-like leaf-branches of a greenhouse asparagus.

branches, or are mere outgrowths of the epidermis (as hairs are).

213. *The foliage of asparagus is composed of modified branches.* The true leaves of asparagus are minute whitish scales (*a*, Fig. 147). The green foliage is produced in the axils of these scales. On the strong spring shoots of asparagus, which are eaten, the true leaves appear as large scales (*a*, *a*, Fig. 148). These large scales persist on the base of the asparagus plant, even in the fall. In the species of greenhouse or ornamental asparagus, the delicate foliage is also made up of green leaf-like branches (Fig. 149). In some cases the true leaves fall after a time, and there is little evidence left. The strong new shoots usually show the true leaves plainly (as in Fig. 150). Branches which simulate leaves are known as **cladophylla** (singular, **cladophyllum**). The broad flat leaves of florists' smilax (common in glasshouses) are cladophylla.



151. Phyllodia of acacia. These Australian trees are sometimes grown in glasshouses.



150. Strong new shoot of Asparagus Sprengeri, showing the true leaves and the branches springing from their axils.

214. In the study of morphology, it is not enough, however, merely to determine whether a part represents root, stem, or leaf: one must determine what part or kind of root, stem, or leaf

it stands for. For example, the foliage in Fig. 151 represents green expanded *petioles*. These leaf-like members bear buds (which produce branches) in their axils, and they have the arrangement or phyllotaxy of leaves; therefore they are considered to be true leaf parts. But they stand edgewise as if they might be petioles; sometimes they bear leaf-blades; other acacias have compound expanded leaves; there are intermediate forms or gradations between different acacias; young seedlings sometimes show intermediate forms. From all the evidence, it is now understood that the foliage of the simple-leaf acacias represents leaf-like petioles. Such petioles are known as **phyllodia** (singular, **phyllodium**).

152. The thorns are in the axils of leaves.

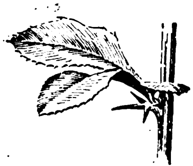
153. Two or more buds are borne in the axils.

215. Thorns and strong spines are usually branches. The spines of hawthorns or thorn-apples are examples: they are borne in the axils of leaves as branches are (Fig. 152); hawthorns usually bear two or more buds in each axil (Fig. 153), and one or two of these buds often grow the following year into normal leafy branches (Fig. 154); sometimes the thorn itself bears leaves (Fig. 155). The thorns of wilding pears, apples, and plums are short, hardened branches. In well-cultivated trees there is sufficient vigor to push the main branch into longer and

154. Some of the buds produce leafy branches.

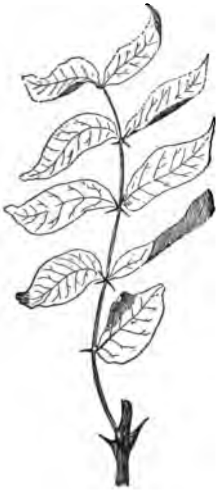
155. The thorn may bear leaves.

softer growth, so that the side buds do not have a chance to start. The thorns of osage orange and honey locust are also branches. Those of the honey locust usually arise from supernumerary buds which are borne somewhat above the axils.



156. Leaf-spine of barberry.

216. *Prickles, bristles, and weak spines, which have a definite arrangement on the stem, are usually modified* **leaves or parts of leaves.** The spines of thistles are hardened points of leaf-lobes. The spines of the barberry are reduced leaves; in their axils are borne short branches or leaf-tufts (Fig. 156); in spring on young shoots may be found almost complete gradations from spiny leaves to spines. In the prickly ash the prickles are stipules and stipels. The reasons for interpreting them so are apparent in Fig. 157. Stipular prickles may also be seen in the common or acacia locust (robinia).



157. Stipular prickles of prickly ash.

217. *Prickles, bristles, and hairs, which are scattered or have no definite arrangement, are usually mere* **out-growths of the epidermis.** They usually are removed with the bark. Of such are the prickles of squashes, briars (Fig. 158), and roses.

158. Prickles of dewberry.

218. The reason for the existence of spines is difficult to determine. In many or most cases they seem to have no distinct use or function. In some way they are associated with the evolution of the plant,

and one cannot determine why they came without knowing much of the genealogy of the plant. In some cases they seem to be the result of the contraction of the plant-body, as in the cacti and other desert plants; and they may then serve a purpose in lessening transpiration. It is a common notion that spines and prickles exist for the purpose of keeping enemies away, and that hairs keep the plant warm, but these ideas usually lack scientific accuracy. Even if spines do keep away browsing animals in any plant, it is quite another question why the spines came to be. To answer the question what spines and hairs are for demands close scientific study of each particular case, as any other problem does.

159. The diminishing leaves of boneset.

219. Leaves are usually smaller as they approach the flowers (Fig. 159). *They often become so much reduced as to be mere scales, losing their office as foliage.* In their axils, however, the flower-branches may be borne (Fig. 160). Much-reduced leaves, particularly those which are no longer green and working members, are called **bracts**. In some cases, large colored bracts are borne just beneath the flowers and look like petals: the flowering dogwood is an example; also the bougainvillea, which is common in glasshouses

160. The uppermost flowers are borne in the axils of bracts.—Fuchsia.

(Fig. 161) ; also the scarlet sage of gardens and the flaming poinsettia of greenhouses.

220. **The scales of buds are special kinds of bracts.** In some cases each scale represents an entire leaf; in others, it represents a petiole or stipule. In the expanding pear, maple, lilac, hickory, and horse-chestnut buds, note the gradation from dry scales to green leaf-like bodies. When the winter scales fall by the pushing out of the young shoot, scars are left: these scars form "rings," which mark the annual growths. See Chap. VII. **The scales of bulbs are also special kinds of leaves or bracts.** In some cases they are merely *protective bodies;* in others they are *storehouses.* We have found (45) that the presence of scales or bracts is one means of distinguishing underground stems from roots.

161. In the bougainvillea three gaudily colored bracts surround each cluster of three small flowers.

Review.—What are considered to be the fundamental or type forms from which the parts of plants are derived? How do the forms of plants interest us? What is morphology? What is meant by transformation and modification as used by the morphologist? What is meant by homologous parts? Analogous parts? Tell how one may determine the morphology of any part. What is a cladophyllum? Phyllodium? Show a specimen of one or the other, or both (canned asparagus can always be had in the market). What is the morphology of most thorns? Explain the thorns of hawthorn. What are bristles, prickles, and hairs? Why do spines and bristles exist? Explain what a bract is. A bud-scale. A bulb-scale.

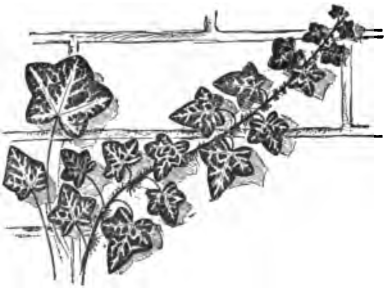
CHAPTER XVI

HOW PLANTS CLIMB

221. We have seen that plants struggle or contend for a place in which to live. Some of them become adapted to grow in the forest shade, others to grow on other plants as epiphytes, others to **climb to the light.** Observe how woods grapes, and other forest climbers, spread their foliage on the very top of the forest tree, while their long flexile trunks may be bare.

222. There are several ways in which plants climb, but most climbers may be classified into four groups: (1) **scramblers,** (2) **root-climbers,** (3) **tendril-climbers,** (4) **twiners.**

223. **SCRAMBLERS.**— Some plants rise to light and air **by resting their long and weak stems on the tops of bushes and quick-growing herbs.** Their stems are elevated by the growing twigs of the plants on which they recline. Such plants are scramblers. Usually they are provided with prickles or bristles. In most weedy swamp thickets, scrambling plants may be found. Briars, some roses, bedstraw or galium, bittersweet (Solanum Dulcamara, not the celastrus), the tear-thumb polygonums, and other plants are familiar examples of scramblers.

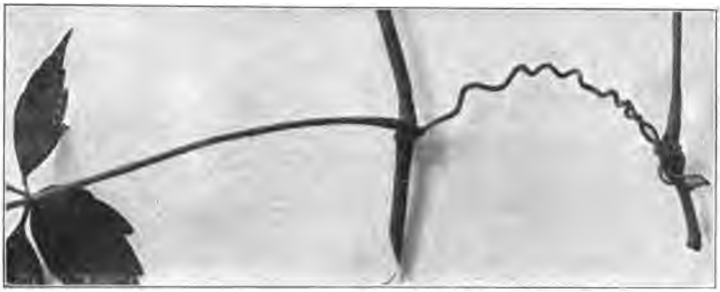


162. A root-climber.—The English ivy.

224. **ROOT-CLIMBERS.**— Some plants climb by means of **true roots,** as explained in paragraph 31. These roots

seek the dark places and therefore enter the chinks in walls and bark. Fig. 12, the trumpet creeper, is a familiar example. The true or English ivy, which is often grown to cover buildings, is another instance (Fig. 162). Still another is the poison ivy. Roots are distinguished from stem tendrils by their **irregular or indefinite position** as well as by their mode of growth.

225. **TENDRIL-CLIMBERS.**— A slender coiling part which serves to hold a climbing plant to a support is known as a **tendril.** The free end swings or curves until it strikes some object, when it attaches itself and then coils and *draws the plant close to the support.* The spring of the coil also allows the plant *to move in the wind*, thereby enabling the plant to maintain its hold. Slowly pull a well-matured tendril from its support, and note how strongly it holds on. Watch the tendrils in a storm. To test the movement of a free tendril, draw an ink line lengthwise of it, and note that the line is now on the concave side and now on the convex side. Of course this movement is slow, but it is often evident in an hour or so. Usually the tendril attaches to the support by *coiling about it*, but the Virginia creeper and Boston ivy attach to walls by means of *disks* on the ends of the tendrils.

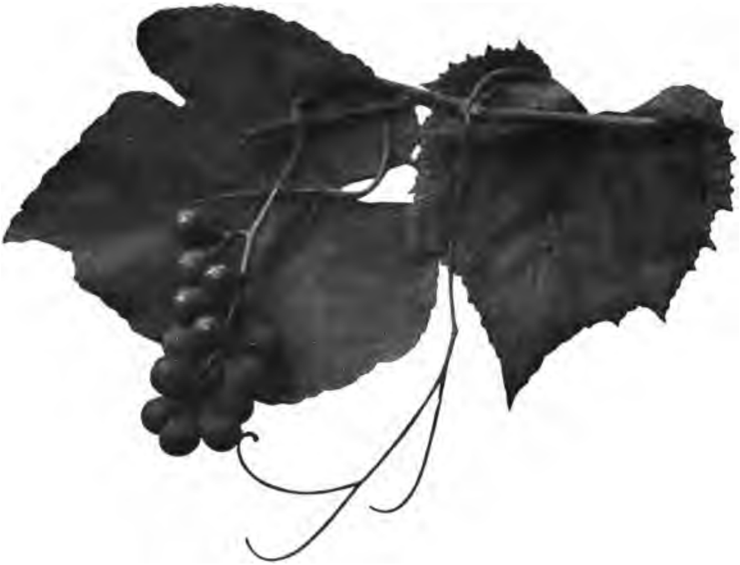


163. Tendril of Virginia creeper. The direction of the coil changes near the middle.

226. Since both ends of the tendril are fixed, when it

finds a support, the coiling would tend to twist it in two. It will be found, however, that the tendril **coils in different directions** in different parts of its length. In Fig. 163 the change of direction in the coil occurs at the straight place near the middle. In long tendrils of cucumbers and melons there may be several changes of direction.

227. Tendrils may be either **branches or leaves.** In the Virginia creeper and grape they are branches; they stand opposite the leaves in the position of fruit-clusters (Fig. 164), and sometimes one branch of a fruit-cluster is a tendril. These tendrils are therefore homologous with fruit-clusters, and fruit-clusters are branches.

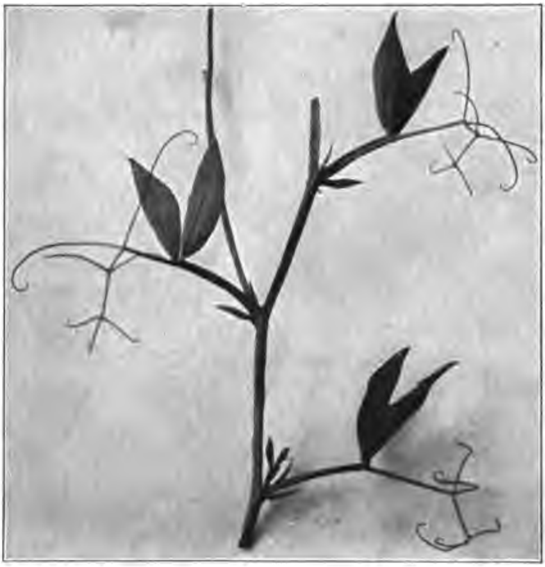


164. The fruit-cluster and tendril of grape are homologous.

228. In some plants tendrils are **leaflets.** Examples are the sweet pea (Fig. 165) and common garden pea. In Fig. 165, observe the leaf with its two stipules, petiole,

two normal leaflets, and two or three pairs of leaflet-tendrils and a terminal leaflet-tendril. The cobea, a common garden climber, has a similar arrangement. In some cases tendrils are **stipules**, as probably in the green-briars (smilax).

229. The **petiole** or **midrib** *may act as a tendril*, as in various kinds of clematis. In Fig. 166, two opposite leaves are attached at *a*. Each leaf is pinnately compound and has two pairs of leaflets and a terminal leaflet. At *b* and *c* the midrib or rachis has wound about a support. The petiole and the petiolules may behave similarly. Examine the tall-growing nasturtiums in the garden.

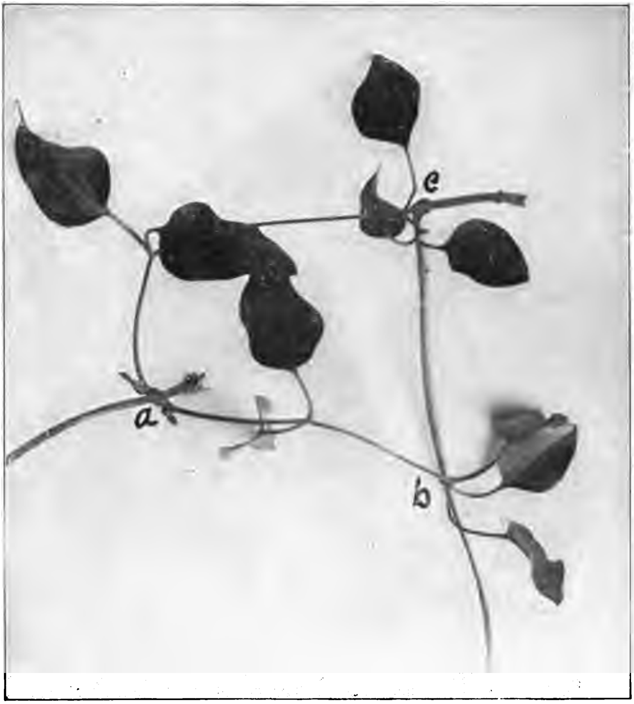


165. In the sweet pea (and garden pea) the leaflets are tendrils.

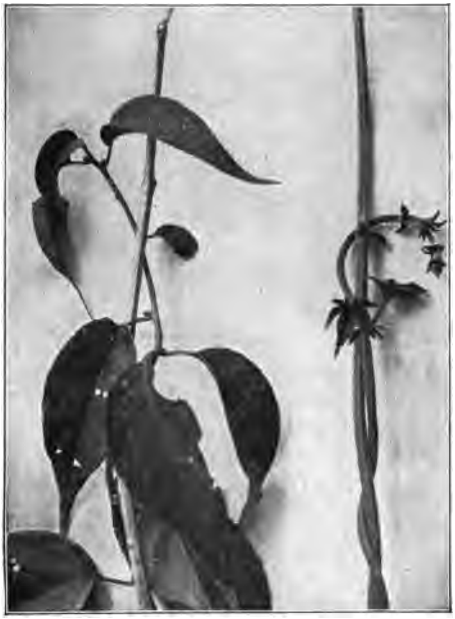
230. **TWINERS.**—The entire plant or shoot may wind about a support. Such a plant is a **twiner.** Examples are bean, hop, morning-glory, moon-flower, false bitter-

sweet or wax-work (celastrus), some honeysuckles, wistaria, Dutchman's pipe, dodder. The free tip of the twining branch *sweeps about in curves*, much as the tendril does, until it finds support or becomes old and rigid.

231. Each kind of plant usually coils *in only one direction*. Most plants coil against the sun, or from the observer's left across his front to his right as he faces the plant. Such plants are said to be **dextrorse** (right-handed) or **antitropic** (against the sun). Examples are bean, morning-glory. The hop twines from the observer's right to his left. Such plants are **sinistrorse** (left-handed) or



166. Clematis climbs by means of its leaf-stalks.

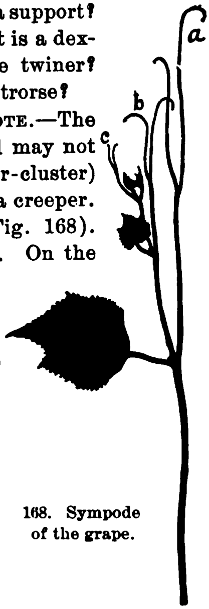


167. Dextrorse and sinistrorse twiners.—False bitter-sweet and hop.

eutropic (with the sun). Fig. 167 shows the two directions.

Review.—Why do plants climb? How do they climb? Explain what is meant by scramblers. By root-climbers. What is a tendril? How does it find a support? Why and how does it coil? How does it grasp its support? What is the morphology of the tendril of Virginia creeper? Why? Of the pea? Of the clematis? What is a twiner? How does it find a support? What is a dextrorse twiner? Sinistrorse?

Note.—The pupil may not understand why the branch (as tendril and flower-cluster) stands opposite the bud in the grape and Virginia creeper. Note that a grape-shoot ends in a tendril (*a*, Fig. 168). The tendril represents the true axis of the shoot. On the side a leaf is borne, from the axil of which the branch grows to continue the shoot. This branch ends in a tendril, *b*. Another leaf has a branch in its axil, and this branch ends in the tendril *c*. The real apex of the shoot is successively turned aside until it appears to be lateral. That is, the morphologically terminal points of the successive shoots are the tendrils, and the order of their appearing is *a*, *b*, *c*. The tendrils branch: observe the minute scale representing a leaf at the base of each branch. This type of branching—the axial growth being continued by successive lateral buds—is *sympodial*, and the branch is a *sympode*. Continuous growth from the terminal bud is *monopodial*, and the branch is a *monopode*.



168. Sympode of the grape.

CHAPTER XVII

FLOWER-BRANCHES

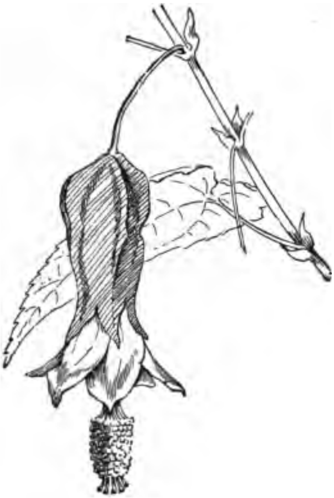
232. We have (86) seen that branches arise from the axils of leaves. Sometimes the leaves may be reduced to bracts and yet branches are borne in their axils. Some of the branches grow into long limbs; others become short spurs; *others bear flowers.*

169. **Terminal flowers of the white-weed (in some places called ox-eye daisy).**

233. Flowers are usually borne near the top of the plant, since the plant must grow before it blooms. Often they are produced in great numbers. It results, therefore, that flower-branches usually stand close together, forming a **cluster.** The shape and arrangement of the flower-cluster *differ with the kind of plant*, since each plant has its own mode of branching.

234. Certain definite or well-marked types of flower-clusters have received names. Some of these names we shall discuss, but the flower-clusters which perfectly match the definitions are the exception rather than the rule. The determining of the kinds of flower-clusters is one of the most per-

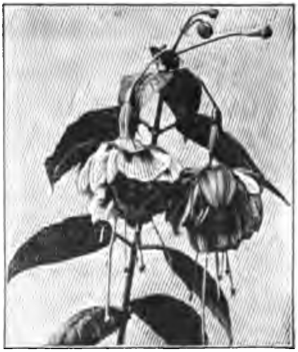
plexing subjects in descriptive botany. We may classify the subject around three ideas: **solitary flowers, corymbose clusters, cymose clusters.**



170. Lateral flower of abutilon.

235. **SOLITARY FLOWERS.**— In many cases flowers are borne singly. They are then said to be **solitary.** The solitary flower may be either at the end of the main shoot or axis (Fig. 169), when it is said to be **terminal,** or from the side of the shoot (Fig. 170), when it is said to be **lateral.** The lateral flower is also said to be **axillary.**

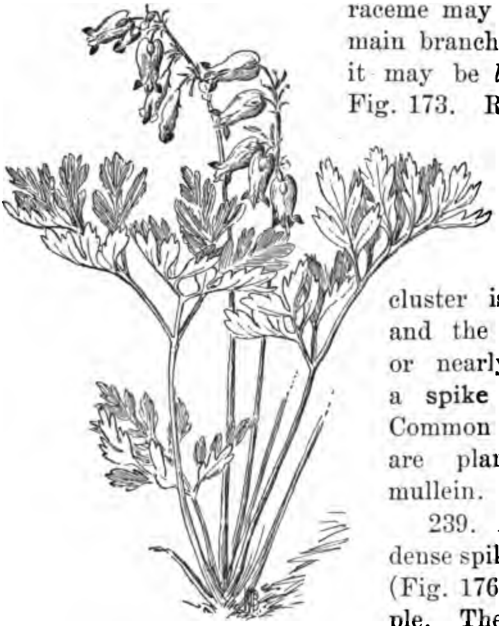
236. **CORYMBOSE CLUSTERS.**— If the flower-bearing axils were rather close together, an open or leafy flower-cluster might result, as in Fig. 171. The fuchsia continues to grow from the tip, and the older flowers are left farther and farther behind. If the cluster were so short as to be flat or convex on top, the outermost flowers would be the older. A flower-cluster in which the lower or outer flowers open first is said to be a **corymbose cluster.** It is sometimes said to be an **indeterminate** cluster, since it is the result of a type of growth which may go on more or less continuously from the apex.



171. Leafy flower-cluster of fuchsia.

237. The simplest form of a definite corymbose cluster is a **raceme,** which is an unbranched open cluster in which

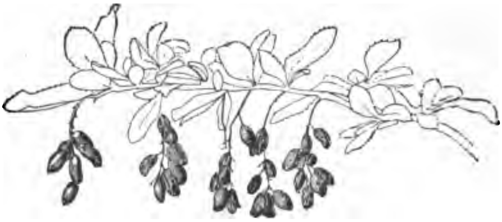
the flowers are borne on short stems and open from below (that is, from the older part of the shoot) upwards. The raceme may be *terminal* to the main branch, as in Fig. 172, or it may be *lateral* to it, as in Fig. 173. Racemes often bear the flowers on one side of the stem, or in a single row.



172. Terminal racemes of dicentra.

238. When a corymbose flower-cluster is long and dense and the flowers are sessile or nearly so, it is called a **spike** (Figs. 174, 175). Common examples of spikes are plantain, mignonette, mullein.

239. A very short and dense spike is a **head.** Clover (Fig. 176) is a good example. The sunflower and related plants bear many small flowers in a very dense head. This special kind of head of the sunflower, thistle, and aster tribes has been called an *anthodium*, but this word is little used. Note that in the sunflower (Fig. 177) the outside or exterior flowers open first. Another special form of spike is the **catkin,** which usually has scaly bracts and the whole cluster is deciduous after flowering or fruit-



173. Lateral racemes (in fruit) of barberry.

ing, and the flowers (in typical cases) have only one sex. Examples are the "pussies" of willows (Fig. 213) and flower-clusters of oaks (Fig. 212), hickories, poplars.

240. When a loose, elongated corymbose flower-cluster branches, or is compound, it is called a **panicle.** Because of the earlier growth of the lower branches, the panicle is usually broadest at the base or conical in outline. True panicles are not common.

175. Loose spikes of false dragon's head or physostegia.

174. Spike of hyacinth. Note, also, that the flowers and foliage are produced from the stored food in the bulb, only water being given.

241. When an indeterminate flower-cluster is short, so that the top is convex or flat, it is a **corymb** (Fig. 178). The outermost flowers open first. Fig. 179 shows many corymbs of the bridal wreath, one of the spireas.

242. When the branches of an indeterminate cluster arise from a common point, like the frame of an umbrella, the cluster is an **umbel** (Fig.180). Typical umbels occur in carrot, parsnip, parsley and other plants of the parsley family: the family is known as the

176. Head of crimson clover.

177. Head of sunflower.

Umbelliferæ, or umbel-bearing family. In the carrot and many other Umbelliferæ, there are small or secondary umbels, called **umbellets**, at the end of each of the main branches. (In the center of the wild carrot umbel one often finds a single, blackish, often aborted flower, comprising a 1-flowered umbellet.)

179. Corymbs of the bridal wreath (spirea).

243. **CYMOSE CLUSTERS.**—When the terminal or **central flower** opens first, the cluster is said to be **cymose.** The growth of the shoot or cluster is **determinate,** since the length is definitely determined or stopped by the terminal flower. Fig. 181 shows a determinate or cymose mode of flower-bearing.

244. Dense cymose clusters are usually flattish on top because of the cessation of growth in the main or central axis. These compact flower-clusters are known as **cymes.** Apples, pears (Fig. 182) and cherries bear flowers in cymes. Some cymes look very like umbels (as in Fig. 183). A head-like cymose cluster is a **glomerule**: it blooms from the top downwards rather than from the base upwards.

178. Corymb of candytuft.

180. Compound umbel of wild carrot.

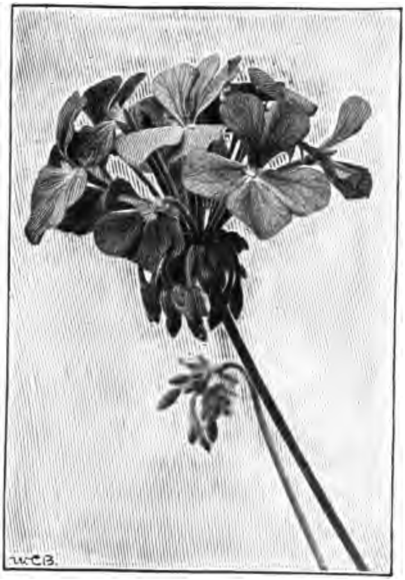
245. **MIXED CLUSTERS.**— Often the cluster is **mixed,** being determinate in one part and indeterminate in another part of the same cluster. This is the case in Fig. 184. The main cluster is indeterminate, but the branches are determinate. The cluster has the appearance of a panicle, and is usually so called, but it is really a **thyrse.** Lilac is a familiar example of a thyrse. In some cases, the main cluster is determinate and the branches are indeterminate, as in hydrangea and elder. Such clusters are **corymbose cymes.**

181. Determinate or cymose arrangement. — Wild geranium.

246. **INFLORESCENCE.**—The *mode* or *method* of flower arrangement is known as the **inflorescence.** That is, the inflorescence is cymose, corymbose, paniculate, spicate, solitary. By custom, however, the word inflorescence has come to be used for the *flower-cluster itself* in works on descriptive botany. Thus a cyme or a panicle may be called an inflorescence. It will be seen that even solitary flowers follow either indeterminate or determinate methods of branching.

182. Cyme of pear. Compare Fig. 63.

247. **THE FLOWER-STEM.**— The stem of a solitary flower is known as

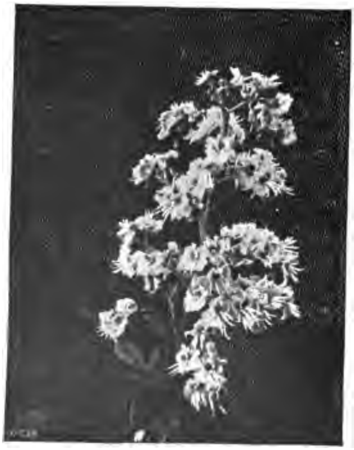


183. An umbel-like cyme.—Geranium.

a **peduncle**; also the general stem of a *flower-cluster*. The stem of the individual flower in a cluster is a **pedicel.**

248. In the so-called stemless plants (37) the peduncle may arise directly from the ground, or crown of the plant, as in dandelion, hyacinth (Fig. 174), garden daisy (Fig. 185). This kind of peduncle is called a **scape.** A scape may bear one or many flowers. It has no foliage leaves, but it may have bracts.

REVIEW.—What is the homology of flower-branches? How is it that flowers are often borne in clusters? Explain what may be meant by a solitary flower. What are the two types of flower-clusters? What are corymbose clusters? Define raceme. Spike. Head and anthodium. Catkin. Panicle. Umbel. Umbellet. Corymb. What are cymose clusters? What is a cyme? Glomerule? Contrast indeterminate and determinate modes of branching. Explain mixed clusters. What is a thyrse? What is meant by the word inflorescence? Define peduncle, pedicel, and scape.



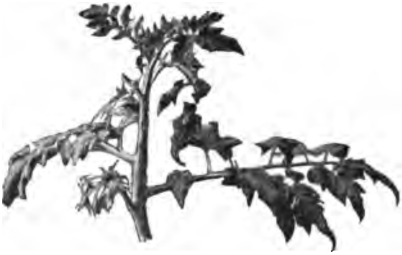
184. Thyrse of horse-chestnut.

NOTE.—In the study of flower-clusters, it is well to select first

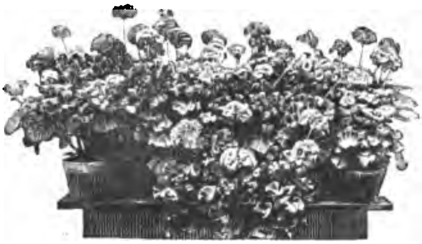
185. Scapes of the true or English daisy.

those which are fairly typical of the the various classes discussed in the preceding paragraphs. As soon as the main types are well fixed in the mind, random clusters should be examined, for the pupil must never receive the impression that all flower-clusters follow the definitions in books. Clusters of some of the commonest plants are very puzzling, but the pupil should at least be able to discover whether the inflorescence is determinate or indeterminate.

In the tomato (Fig. 186) the flower-cluster is opposite the leaf. Examine blooming tomato plants, and determine the method of this inflorescence. Compare the grape. In some cases the flower-cluster ends in a leaf, suggesting that the cluster is morphologically a leaf; but see whether there is not a joint between the cluster and the leaf, showing that the leaf is attached to a branch. The flower-cluster of the tomato has been greatly modified by cultivation. It was originally distinctly racemose.



186. Tomato shoot.



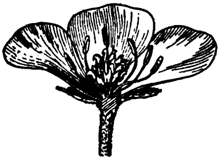
Geraniums in the school-room window.

CHAPTER XVIII

THE PARTS OF THE FLOWER

249. The flower exists for the purpose of **producing seed.** It is probable that all its varied forms and colors contribute to this supreme end. These forms and colors please the human fancy and make living the happier, but the flower exists for the good of the plant, not for the good of man. The parts of the flower are of two general kinds — those which are directly concerned in the *production of seeds*, and those which act as covering and *protecting organs*. The former parts are known as the **essential organs**; the latter as the **floral envelopes.**

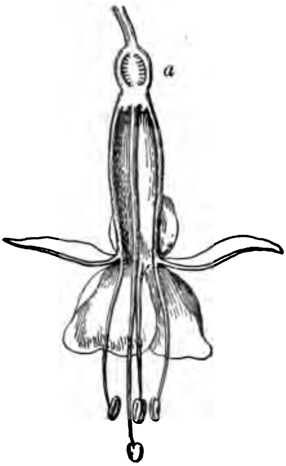
250. **ENVELOPES.**—The floral envelopes usually bear a close resemblance to leaves. These envelopes are very commonly of two series or kinds—the *outer* and the *inner*. The outer series, known as the **calyx,** is usually smaller and green. It usually comprises the outer cover of the flower-bud. The calyx is the lowest whorl in Fig. 187. The inner series, known as the **corolla,** is usually colored and more special or irregular in shape than the calyx. It is the showy part of the flower, as a rule. The corolla is the second or large whorl in Fig. 187. It is the large part in Fig. 188.


187. Flower of a buttercup in section.

188. Flower of buttercup.

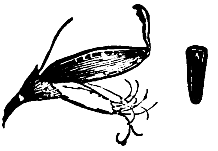
251. The calyx may be composed of several leaves. **Each leaf is a sepal.** If it is of one piece, it may be

lobed or divided, in which case the divisions are called **calyx-lobes.** In like manner, the corolla may be composed of **petals,** or it may be of one piece and variously lobed. A calyx of one piece, no matter how deeply lobed, is **gamosepalous.** A corolla of one piece is **gamopetalous.** When these series are of separate pieces, as in Fig. 187, the flower is said to be **polysepalous** and **polypetalous.** Sometimes both series are of separate parts, and sometimes only one of them is so formed.

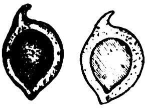


189. Flower of fuchsia in section.

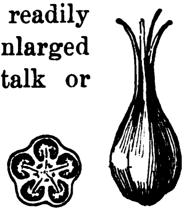
252. *The floral envelopes are homologous with leaves.* Sepals and petals, at least when more than three or five, are each in more than one whorl, and one whorl stands below another so that the parts overlap. They are borne on the expanded or thickened end of the flower-stalk: this end is the **torus.** In Fig. 187 all the parts are seen as attached to the torus. This part is sometimes called receptacle, but this word is a common-language term of several meanings, whereas torus has no other meaning. Sometimes one part is attached to another part, as in the fuchsia (Fig. 189) in which the petals are borne on the calyx-tube.

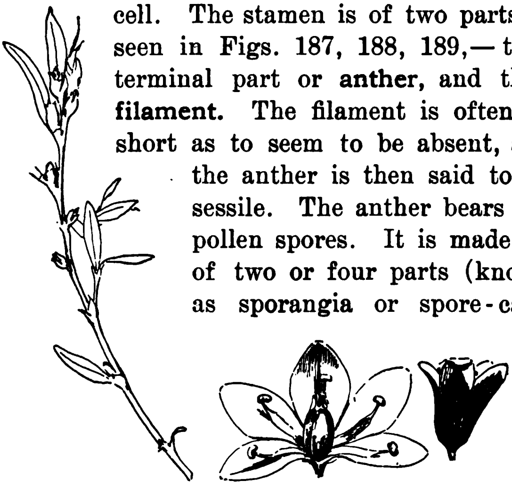

190. Pistil of garden pea, the stamens being pulled down in order to disclose it; also a section, showing the single compartment.

253. **ESSENTIAL ORGANS.**—The essential organs are of two series. They are also homologous with leaves. The outer series is composed of the **stamens.** The inner series is composed of the **pistils.**

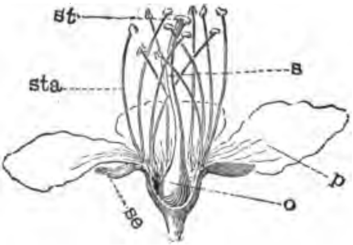

191. Simple pistils of buttercup, one in longitudinal section.

254. Stamens bear the **pollen,** which is made up of grains or spores, each spore usually being a single plant cell. The stamen is of two parts, as readily seen in Figs. 187, 188, 189,— the enlarged terminal part or **anther,** and the stalk or **filament.** The filament is often so short as to seem to be absent, and the anther is then said to be sessile. The anther bears the pollen spores. It is made up of two or four parts (known as sporangia or spore-cases), which burst and discharge the pollen. *When the pollen is shed, the stamen dies.*


192. Compound pistil of a St. John's-wort. It has 5 carpels.


193. Knotweed, a very common but inconspicuous plant along hard walks and roads. Two flowers, enlarged, are shown at the right. These flowers are very small and borne in the axils of the leaves.

255. *Pistils bear the seeds.* The pistil may be of one part or compartment, or of many parts. The different units or parts of which it is composed are **carpels.** Each carpel is homologous with a leaf. Each carpel bears one or more seeds. A pistil of one carpel is **simple;** of two or more carpels, **compound.** Usually the structure of the pistil may be determined by cutting across the lower or seed-bearing part. Figs. 190, 191, 192 explain. A flower may contain *one carpel* (simple pistil) as the pea (Fig. 190); *several separate carpels* or



194. The structure of a plum blossom. *se.* sepals; *p.* petals; *sta.* stamens; *o.* ovary; *s.* style; *st.* stigma. The pistil consists of the ovary, style, and stigma. It contains the seed part. The stamens are tipped with anthers, in which the pollen is borne. The ovary, *o*, ripens into the fruit.

simple pistils, as the buttercup; or a *compound pistil*, as the St. John's-wort (Fig. 192).

256. The pistil, whether simple or compound, has three parts: the lowest or seed-bearing part, which is the **ovary**; the **stigma** at the upper extremity, which is a flattened or expanded surface, and usually roughened or sticky; the stalk-like part or **style**, connecting the ovary and stigma. Sometimes the style is apparently wanting, and the stigma is said to be sessile on the ovary. These parts are shown in the fuchsia, Fig. 189. The ovary or seed vessel is at *a*. A long style, bearing a large stigma, projects from the flower. See, also, Figs. 191 and 194.

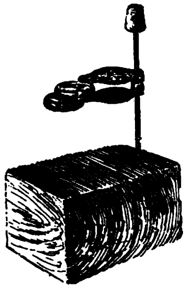
195. Flower of garden nasturtium. Separate petal at *a*. The calyx is prolonged into a spur.

257. **CONFORMATION OF THE FLOWER.**— A flower which has calyx, corolla, stamens, and pistils is said to be **complete**; all others are **incomplete**. In some flowers both the floral envelopes are wanting: such are **naked**. When one of the floral envelope series is wanting, the remaining series is said to be calyx, and the flower is therefore **apetalous** (without petals). The knotweed (Fig. 193), smartweed, buckwheat, elm (Fig. 92), are examples. Some flowers lack the pistils: these are **staminate**, whether the envelopes are missing or not. Others lack the stamens: these are **pistillate**. Others have neither

196. The five petals of the pansy, detached to show the form.

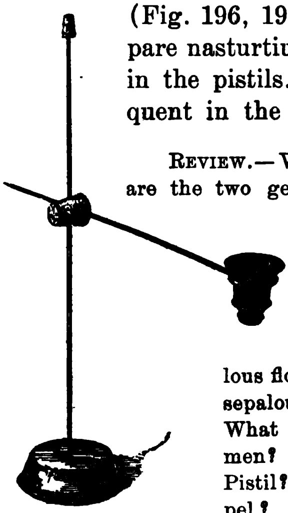
197. Flower of catnip.

stamens nor pistils: these are **sterile** (snowball and hydrangea). Those which have both stamens and pistils are **perfect,** whether or not the envelopes are missing. Those which lack either stamens or pistils are **imperfect** or **diclinous.** Staminate and pistillate flowers are imperfect or diclinous.


198. Improvised stand for lens.

258. Flowers in which the parts of each series are alike are said to be **regular** (as in Figs. 187, 188, 189). Those in which some parts are unlike other parts of the same series are **irregular.** The irregularity may be in calyx, as in nasturtium (Fig. 195); in corolla (Fig. 196, 197); in the stamens (compare nasturtium, catnip Fig. 197, sage); in the pistils. Irregularity is most frequent in the corolla.

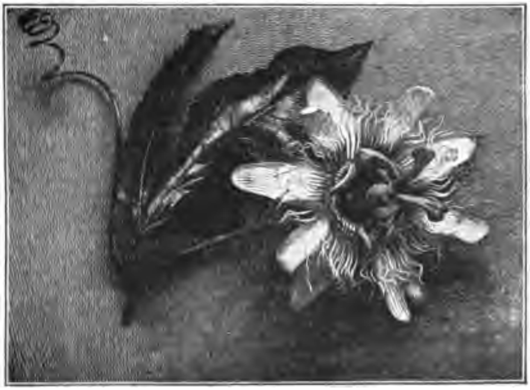
199. Dissecting needle. ½ natural size.


200. Dissecting glass.

REVIEW.—What is the flower for? What are the two general kinds of organs in the flower? What is the homology of the flower-parts? What are floral envelopes? Calyx? Sepals? Calyx-lobes? Corolla? Petals? Corolla-lobes? Gamosepallous flowers? Gamopetalous? Polysepalous? Polypetalous? Define torus. What are the essential organs? Stamen? Filament? Anther? Pollen? Pistil? Style? Stigma? Ovary? Carpel? Define a complete flower. In what ways may flowers be incomplete? Explain perfect and imperfect (or diclinous) flowers. Define regular flowers. In what ways may flowers be irregular?

NOTE.—One needs a lens for the examination of the flower. It is best to have the lens mounted on a frame, so that the pupil has both hands free for pulling the flower in pieces. An ordinary pocket lens may be mounted on a wire in a block, as in Fig. 198. A cork is slipped on the top of the wire to avoid injury to the face. The pupil should be provided with two dissecting needles (Fig. 199), made by securing an ordinary needle in a pencil-like stick. Another convenient arrangement is shown in Fig. 200. A small tin dish is used for the base. Into this a stiff wire standard is soldered. The dish is filled with solder, to make it heavy and firm. Into a cork slipped on the standard; a cross-wire is inserted, holding on the end a jeweler's glass. The lens can be moved up and down and sidewise. This outfit can be made for about seventy-five cents. Fig. 201 shows a convenient hand-rest or dissecting stand to be used under this lens. It may be 16 in. long, 4 in. high, and 4 or 5 in. broad. Various kinds of dissecting microscopes are on the market, and these are to be recommended when they can be afforded.

201. Dissecting stand.



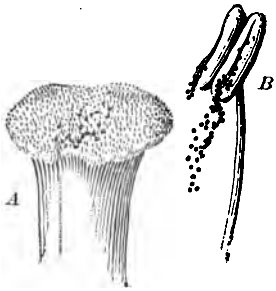
Odd blossom of one of the passion-flowers.

Calyx-lobes and petals are 5. A fringe of hairs (or crown) grows from the petals. The club-shaped stigmas project. The stamens, 5 in number, stand inside the crown.

CHAPTER XIX

FERTILIZATION AND POLLINATION

259. **FERTILIZATION.**—*Seeds result from the union of two elements or parts.* One of these elements, a nucleus of a plant cell, is borne in the pollen-grain. The other element, an egg-cell, is borne in the ovary. The pollen-grain falls on the stigma (Fig. 202). It absorbs the juices exuded by the stigma and grows by sending out a tube (Fig. 203). This tube grows downward through the style, absorbing food as it goes, and finally reaches the egg-cell in the interior of an ovule in the ovary, and **fertilization,** or union of the two nuclei, takes place. **The ovule then ripens into a seed.** The growth of the pollen-tube is often spoken of as germination of the pollen, but it is not germination in the sense in which the word is used when speaking of seeds.

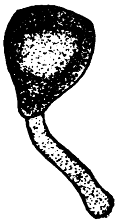


202. *B*, pollen of plum escaping from anther. *A*, pollen germinating on the stigma. Enlarged.

260. Better seeds—that is, those which produce stronger and more fruitful plants — usually result when the *pollen comes from another flower.* Fertilization effected between different flowers is **cross-fertilization**; that resulting from the application of pollen to pistils in the same flower is **close-fertilization** or **self-fertilization.** It will be seen that the cross-fertilization relationship may be of many degrees—between two flowers in the same cluster, between those in different clusters on the same branch, between those on different plants.

Usually fertilization takes place only between plants of the same species or kind.

261. In many cases **the pistil has the power of selecting pollen** when pollen from two or more sources is applied to the stigma. Usually the foreign pollen, if from the same kind of plant, grows and performs the office of fertilization, and pollen from the same flower perishes. If, however, no foreign pollen arrives, the pollen from the same flower may finally grow and fertilize the germ.



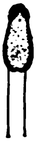
203. Pollen grain germinating. Greatly magnified.

262. In order that the pollen may grow, *the stigma must be ripe.* At this stage the stigma is usually moist and sometimes sticky. A ripe stigma is said to be **receptive.** The stigma may remain receptive for several hours or even days, depending on the kind of plant, the weather, and how soon pollen is received. When fertilization takes place, the stigma dies. Observe, also, how soon the petals wither after the stigma has received pollen.

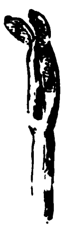
263. **POLLINATION.**—The transfer of the pollen from anther to stigma is known as **pollination.** The pollen may fall of its own weight on the adjacent stigma, or it may be carried from flower to flower by wind, insects, or other agents. There may be **self-pollination** or **cross-pollination.**

264. Usually the pollen is discharged by the bursting of the anthers. The commonest method of discharge is through a *slit* on either side of the anther (Fig. 202). Sometimes it discharges through a *pore* at the apex, as in azalea (Fig. 204), rhododendron, huckleberry, wintergreen. In some plants a part of the anther wall raises or falls as a *lid*, as in barberry (Fig. 205), blue cohosh, May apple. The opening of an anther (as also of a seed-pod) is known as **dehiscence.** When an anther or seed-pod opens it is said *to dehisce.*

265. *Most flowers are so constructed as to increase the chances of cross-pollination.* We have seen (261) that the stigma may have the power of selecting foreign pollen. The commonest means of insuring cross-pollination is the *different times of maturing of stamens and pistils in the same flower.* In most cases the stamens mature first: the flower is then **proterandrous.** When the pistils mature first the flower is **proterogynous.** (*Aner*, *andr*, is a Greek root often used, in combinations, for stamen, and *gyne* for pistil.) The difference in time of ripening may be an hour or two, or it may be a day. The ripening of the stamens and pistils at different times is known as **dichogamy,** and flowers of such character are said to be dichogamous. There is little chance for dichogamous flowers to pollinate themselves. Many flowers are *imperfectly dichogamous*—some of the anthers mature simultaneously with the pistils, so that there is chance for self-pollination in case foreign pollen does not arrive. Even when the stigma receives pollen from its own flower, cross-fertilization may result (261). The hollyhock is proterandrous. Fig. 206 shows a flower recently expanded. The center is occupied by the column of stamens. In Fig. 207, showing an older flower, the long styles are conspicuous.



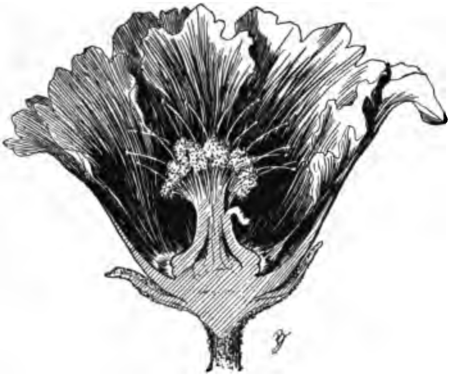
204. Anther of azalea, opening by terminal pores.



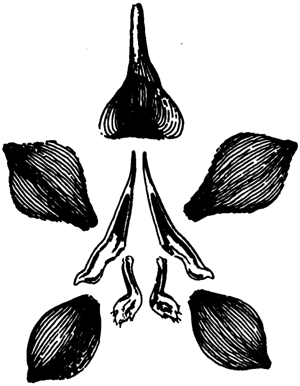
205. Barberry stamen with anther opening by lids.

206. Flower of hollyhock; proterandrous.

266. *Some flowers have so developed as to prohibit self-pollination.* Very irregular flowers are usually of this category. Regular flowers usually depend on dichogamy and the selective power of the pistil to insure crossing. *Flowers which are very irregular and provided with nectar and strong perfume are usually pollinated by insects.* Gaudy colors probably attract insects in many cases, but perfume appears to be a greater attraction. The insect visits the flower for the nectar (for the making of honey) and may unknowingly carry the pollen. Spurs and sacs in the flower are *nectaries*, but in spurless flowers the nectar is usually secreted *in the bottom of the flower-cup.* Flowers which are pollinated by insects are said to be **entomophilous** ("insect-loving"). Fig. 208 shows a larkspur. The envelopes are separated in Fig. 209. The long spur at once suggests insect pollination. The spur is a sepal. Two hollow petals project into this spur, apparently serving to guide the


207. Older flower of hollyhock.

208. Flower of larkspur.


209. Envelopes of a larkspur. There are five wide sepals, the upper one being spurred. There are four small petals.

bee's tongue. The two smaller petals, in front, are differently colored and perhaps serve the bee in locating the nectary. The stamens ensheath the pistils (Fig. 210). As the insect stands on the flower and thrusts his head into its center, the envelopes are pushed downward and outward and the pistil and stamens come in contact with his abdomen. Since the flower is proterandrous, the pollen which the pistils receive from the bee's abdomen must come from another flower. Note a somewhat similar arrangement in the toad-flax or butter-and-eggs (Fig. 211).

210. Stamens of larkspur, surrounding the pistils.

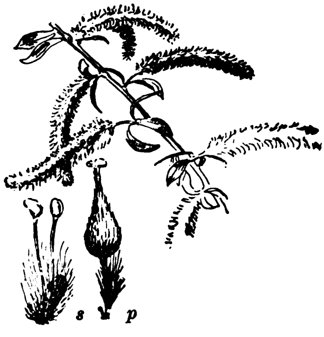
267. *Many flowers are pollinated by the wind.* They are said to be **anemophilous** ("wind-loving"). Such flowers produce great quantities of pollen, for much of it is wasted. They usually have broad stigmas, which expose large surface to the wind. They are usually lacking in gaudy colors and in perfume. Grasses and pine trees are typical examples of anemophilous plants.

211. Toad-flax is an entomophilous flower.

268. In many cases cross-pollination is insured because the *stamens and pistils are in different flowers* (diclinous, 257). When the staminate and pistillate

flowers are on the same plant, e. g., oak (Fig. 212), beech, chestnut, hazel, walnut, hickory, the plant is **monœcious** ("in one house"). When they are on different plants (poplar and willow, Fig. 213), the plant is **diœcious** ("in two houses"). Monœcious and diœcious plants may be pollinated by wind or insects, or other agents. They are usually wind-pollinated, although willows are often, if not mostly, insect-pollinated. The Indian corn (Fig. 214) is a monœcious plant. The staminate flowers are in a terminal panicle (tassel). The pistillate flowers are in a dense spike (ear), inclosed in a sheath or husk. Each "silk" is a style. Each pistillate flower produces a kernel of corn. Sometimes a few pistillate flowers are borne in the tassel and a few staminate flowers on the tip of the ear.

212. Staminate catkins of oak. The pistillate flowers are in the leaf axils, and not shown in this picture.

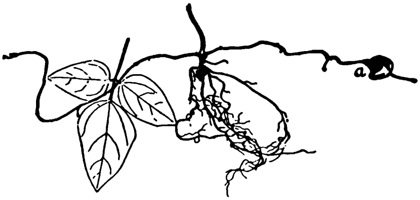


213. Catkins of a willow. A staminate flower is shown at *s*, and a pistillate flower at *p*. The staminate and pistillate are on different plants.

269. Although most flowers are of such character as to insure or increase the chances of cross-pollination, there are some *which absolutely forbid crossing*. These flowers are usually borne beneath or on the ground, and they lack showy colors and perfumes. They are known as **cleistogamous** flowers (meaning "hidden flowers"). The plant has normal showy flowers which may be insect-pollinated, and in addition is provided

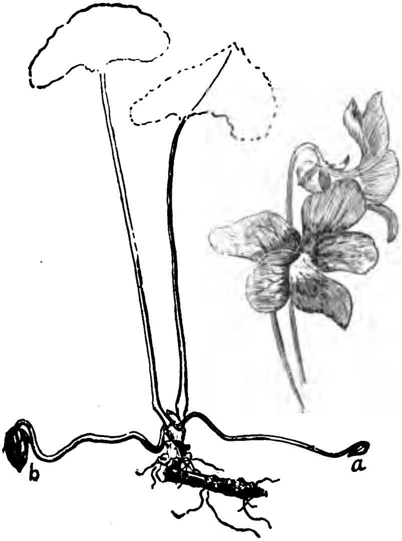
214. Indian corn, a monœcious plant, with staminate flowers borne in the tassel and pistillate flowers borne in the ear.

with these degenerate flowers. Only a few plants bear cleistogamous flowers. Hog-peanut, common blue violet, fringed wintergreen, and dalibarda are the best subjects in the northern states. Fig. 215 shows a cleistogamous flower of the hog-peanut at *a*. Above the true roots, slender rhizomes bear these flowers, which are provided with a calyx and a curving corolla which does not open. Inside are the stamens and pistils. The pupil must not confound the nodules on the roots of hog-peanut with the cleistogamous flowers: these nodules are concerned in the appropriation of food. Late in summer the cleistogamous flowers may be found just underneath the mould. They never rise above ground. The following summer one may find a seedling plant with the remains of the old cleistogamous flower still adhering to the root. The hog-peanut is a common low twiner in woods. It also bears racemes of small pea-like flowers. Cleistogamous flowers usually appear after the showy flowers have passed. They seem to insure a crop of seed by a method which expends little of the plant's energy. See Fig. 216.



215. Hog-peanut, showing a leaf, and a cleistogamous flower at *a*.

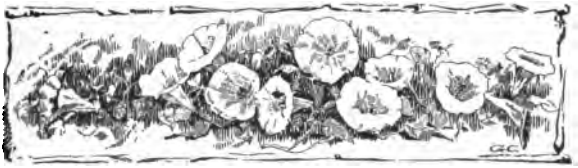
REVIEW.—What is fertilization? Pollination? Define cross- and self-pollination. Which gives the better results, and how? What is meant by the selective power of the pistil? Describe a receptive pistil. Exhibit one. By what agents is cross-pollination secured? How is pollen discharged? What is meant by the word dehiscence? What do you understand by dichogamy? What is its office? How frequent is it? What are entomophilous flowers? Anemophilous? Exhibit or explain one of each. What is the usual significance of irregularity in flowers? Where is the nectar borne? What are monœcious and diœcious plants? Cleistogamous flowers?



216. Common blue violet. The familiar flowers are shown, natural size. The corolla is spurred. Late in the season, cleistogamous flowers are often borne on the surface of the ground. A small one is shown at *a*. A nearly mature pod is shown at *b*. Both *a* and *b* are one-third natural size.

NOTE.—The means by which cross-pollination is insured are absorbing subjects of study. It is easy to give so much time and emphasis to the subject, however, that an inexperienced observer comes to feel that perfect mechanical adaptation of means to end is universal in plants, whereas it is not. One is likely to lose or to overlook the sense of proportions and to form wrong judgments.

In studying cross-pollination, one is likely to look first for devices which prohibit the stigma from receiving pollen from its own flower, but the better endeavor is to determine whether there is any means to insure the application of foreign pollen; for the stigma may receive both but utilize only the foreign pollen. Bear in mind that irregular and odd forms in flowers, strong perfume, bright colors, nectar, postulate insect visitors; that inconspicuous flowers with large protruding stigmas and much dry powdery pollen postulate wind-transfer; that regular and simple flowers depend largely on dichogamy, whether wind- or insect-pollinated. Most flowers are dichogamous.



Funnelform corollas.

CHAPTER XX

PARTICULAR FORMS OF FLOWERS

270. **GENERAL FORMS.** — *Flowers vary wonderfully in size, form, color, and in shapes of the different parts.* These variations are **characteristic of the species or kind of plant.** The most variable part is the corolla. In many cases, the disguises of the parts are so great as to puzzle botanists. Some of the special forms, notably in the orchids, seem to have arisen as a means of adapting the flower to pollination by particular kinds of insects. A few well-marked forms are discussed below in order to illustrate how they may differ among themselves.

271. When in doubt as to the parts of any flower, *look first for the pistils and stamens.* Pistils may be told by the *ovary* or young seed-case. Stamens may be told by the *pollen.* If there is but one series in the floral envelope, the flower is assumed to lack the corolla: it is apetalous (257). The calyx, however, in such cases, may look like a corolla, e. g., buckwheat, elm, sassafras, smartweed, knotweed (Fig. 193). The parts of flowers usually have a *numerical relation to each other,*—they are oftenest in 3's or 5's or in multiples of these numbers. The pistil is often an exception to this order, however, although its compartments or carpels may follow the rule. Flowers on the plan of 5 are said to be **pentamerous**; those on the plan of 3 are **trimerous** (*merous* is from Greek, signifying "member"). In descriptive botanies these words are often written 5-merous and 3-merous.

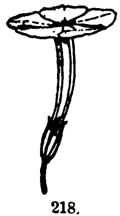
272. The corolla often assumes very definite or distinct forms when gamopetalous. It may have a long tube with

a wide-flaring limb, when it is said to be **funnelform,** as in morning-glory (Fig. 217) and pumpkin. If the tube is very narrow and the limb stands at right angles to it, the corolla is **salverform,** as in phlox (Fig. 218). If the tube is very short and the limb wide-spreading and nearly circular in outline, the corolla is **rotate** or **wheel-shaped,** as in potato (Fig. 219).

217. Funnelform flower of morning-glory.

273. A gamopetalous corolla or gamosepalous calyx is often cleft in such way as to make two prominent parts. Such parts are said to be **lipped** or **labiate.** Each of the lips or lobes may be notched or toothed. In 5-merous flowers, the lower lip is usually 3-lobed and the upper one 2-lobed. Labiate flowers are characteristic of the mint family (Fig. 197), and the family therefore is called the Labiatæ. (Properly, labiate means merely lipped, without specifying the number of lips or lobes; but it is commonly used to designate 2-lipped flowers.) Strongly 2-parted polypetalous flowers may be said to be labiate; but the term is oftenest used for gamopetalous corollas.

219. Rotate flowers of potato.


218. Salver-form flower of phlox.

274. Labiate gamopetalous flowers which are closed in the throat (or entrance to the tube) are said to be grinning or **personate** (personate means *masked*, or *person-like*). Snapdragon is a typical example (Fig. 220); also toad-flax or butter-and-eggs (Fig. 211), and many related plants. Personate flowers usually have definite relations to insect

pollination. Observe how a bee forces his head into the closed throat of the toad-flax.

275. **LILY FLOWERS.**— In plants of the lily family (Liliaceæ) the flowers are typically 3-merous, having three sepals, three petals, six stamens and a 3-carpelled pistil. The parts in the different series are distinct from each other (excepting the carpels,) and mostly free from other series. The sepals and petals are so much alike that they are distinguished chiefly by position, and for this reason the words calyx and corolla are not used, but the floral envelopes are called the **perianth** and the parts are **segments.** Flowers of lilies and trilliums (Fig. 221) answer these details. Not all flowers in the lily family answer in all ways to this description. The term perianth is used in other plants than the Liliaceæ.

220. Personate flowers of snapdragon.

276. **PAPILIONACEOUS FLOWERS.** — In the pea and bean tribes the flower has a special form (Fig. 222). The calyx is a shallow 5-toothed tube. The corolla is composed of four pieces,—the large expanded part at the back, known as the *standard* or *banner;* the two hooded side pieces, known as the *wings;* the single boat-shaped part beneath the wings, known as the *keel.* The keel is supposed to represent two united petals, since the calyx and stamens are in 5's or multiples of 5; moreover, it is composed of two distinct parts in cassia (Fig. 223) and some other plants of the pea family. Flowers of the

221. Flower of trillium.

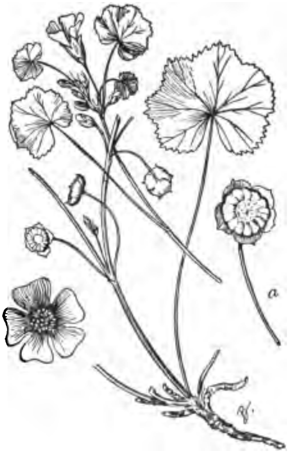
222. Papilionaceous flowers.— Sweet pea.

pea shape are said to be **papilionaceous** (Latin *papilio*, a butterfly).

277. Flowers of the pea and its kind have a peculiar arrangement of stamens. The stamens are 10, of which 9 are united into a tube which incloses the pistil. The tenth stamen lies on the upper edge of the pistil. The remains of these stamens are seen in Fig. 190. The stamens are said to be **diadelphous** ("in two brotherhoods") when united into two groups. Stamens in one group would be called **monadelphous**, and this arrangement occurs in some members of the Leguminosæ or pea family.

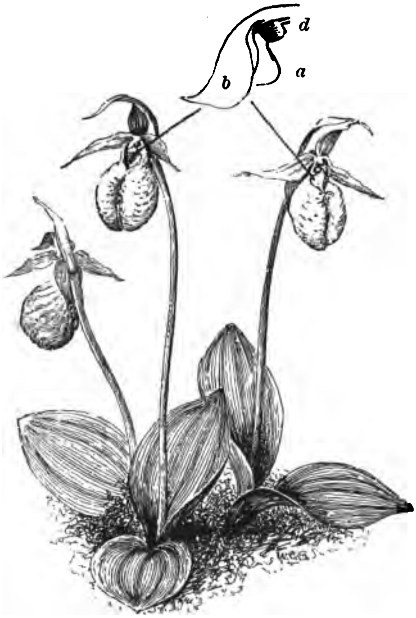
223. Cassia flower, showing the separate keel petals.

278. **MALLOW FLOWERS.** — The flowers of the mallow family are well represented in single hollyhocks (Figs. 206, 207) and in the little plant (Fig. 224) known as "cheeses." The peculiar structure is the column formed by the united filaments, the inclosed styles, and the ring of ovaries at the bottom of the style-tube. The flower is 5-merous. Count the ovaries. They sit on the torus, but are



224. Common mallow, a trailing plant to which the circle of fruits, *a*, gives the names "cheeses" and "shirt button plant."

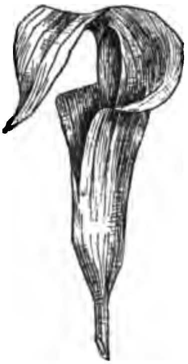
united in the center by the base of the style-tube, which forms a cone-shaped body that separates from the torus when the fruit is ripe. Do all of the ovaries develop, or are some crowded out in the struggle for existence? The calyx is often reinforced by bracts, which look like an extra calyx. These bracts form an **involucre.** An involucre is a circle or whorl of bracts standing just below a flower or a flower-cluster. The umbel of wild carrot (Fig. 180) has an involucre below it. A large family of plants, known as the Malvaceæ or Mallow family, has flowers similar to those of the hollyhock. To this family belong marsh mallow, althea, okra, cotton. Observe that even though the hollyhock is a great tall-growing showy plant and the "cheeses" is a weak trailing inconspicuous plant, they belong to the same family, as shown by the structure of the flowers.



225. A lady's-slipper, to illustrate the orchid family.

279. **ORCHID FLOWERS.**—The flowers of orchids vary wonderfully in shape, size, and color. Most of them are specially adapted to insect pollination. The distinguishing feature of the orchid flower, however, is the union of stamens and pistil in one body, known as the **column.** In Fig. 225 the stemless lady's-slipper is shown. The flower is 3-merous. One of the petals is developed into a great

sac or "slipper," known as the *lip*. Over the opening of this sac the column hangs. The column is shown in detail: *a* is the stigma; *d* is an anther, and there is another similar one on the opposite side, but not shown in the picture; *p* is a petal-like stamen, which does not produce pollen. In most other orchids there are three good anthers. In orchids the pollen is usually borne in adherent masses, one or two masses occupying each sporangium of the anther, whereas in most plants the pollen is in separate grains. These pollen-masses are known technically as **pollinia.** Orchids from the tropics are much grown in choice greenhouses. Several species are common in woods and swamps in the northern states and Canada.



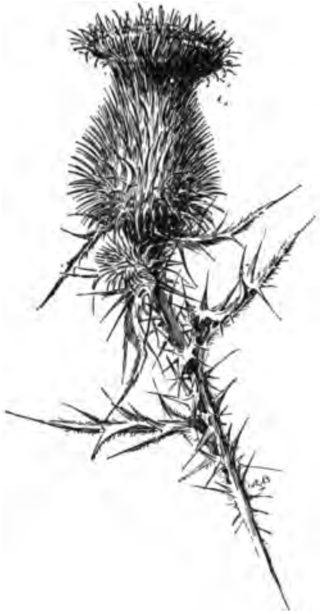
226. Jack-in-the-pulpit. "Jack" is the spadix; the "pulpit" is the spathe.

280. **SPATHE FLOWERS.**—In many plants, very simple (often naked flowers) are borne in dense, more or less fleshy spikes, and the spike is inclosed in or attended by a large corolla-like leaf, known as a **spathe.** The spike of flowers is technically known as a **spadix.** This type of flower is characteristic of the great arum family, which is chiefly tropical. The commonest wild representatives in the North are Jack-in-the-pulpit or Indian turnip (Fig. 226) and skunk cabbage. In the former the flowers are all diclinous and naked. The pistillate flowers (comprising only a 1-loculed ovary) are borne at the base of the spadix, and the staminate flowers (each of a few anthers) are above them. The ovaries ripen into red berries. In the skunk cabbage all the flowers

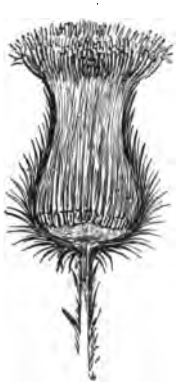
227. Wild aster, with six heads, each containing several florets.

are perfect and have four sepals. The common calla lily is a good example of this type of inflorescence.

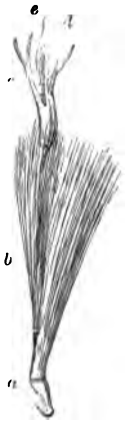
281. **COMPOSITOUS FLOWERS.**—The head (anthodium) or so-called "flower" of sunflower (Fig. 177), thistle, aster (Fig. 227), dandelion, daisy, chrysanthemum, golden-rod, *is composed of several or many little flowers, or* **florets.** These florets are inclosed in a more or less dense and usually green involucre. In the thistle (Fig. 228) this involucre is prickly. A longitudinal section (Fig. 229) discloses the florets, all attached at bottom to a common torus, and densely packed in the involucre. The pink tips of these florets constitute the showy part of the head.



228. Head of pasture thistle, showing the high prickly involucre.



229. Longitudinal section of thistle head.

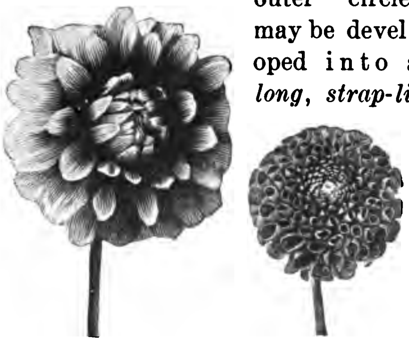


230. Floret of thistle.

282. Each floret of the thistle (Fig. 230) is a complete flower. At *a* is the ovary. At *b* is a much-divided plumy calyx, known as the **pappus.** The corolla is long-tubed, rising above the pappus, and is enlarged and 5-lobed at

231. Cornflower or bachelor's button, in which the outer florets are large and showy.

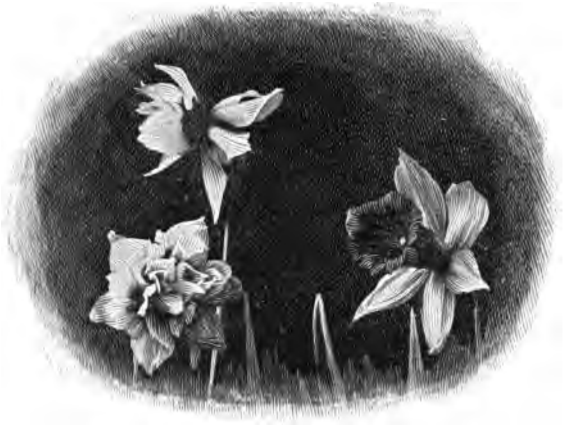
the top, *c*. The style projects at *e*. The five anthers are united about the style in a ring at *d*. Such anthers are said to be **syngenesious.** These are the various parts of the florets of the Compositæ. In some cases the pappus is in the form of barbs, bristles, or scales, and sometimes it is wanting. The pappus, as we shall see later, assists in distributing the seed. Often the florets are not all alike. The corolla of those in the outer circles may be developed into a *long, strap-like or tubular part*, and the head then has the appearance of being one flower with a border of petals. Of such is the sunflower (Fig. 177), aster (Fig. 227), bachelor's button or corn flower (Fig. 231), and field daisy (Fig. 169). These long corolla-limbs are called **rays.** In some cultivated composites, all the florets may develop rays, as in the dahlia (Fig. 232), and chrysanthemum. In some species, as dandelion, all the florets naturally have rays. Syngenesious arrangement of anthers is the most characteristic single feature of the composites.

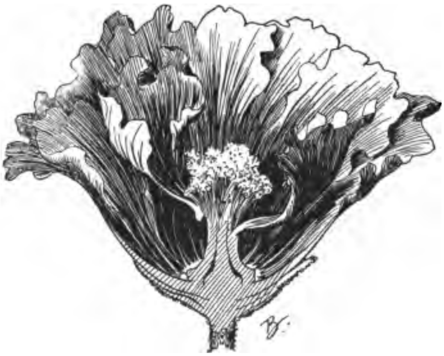


232. Double dahlias. In one, the florets have developed flat rays. In the other, the florets appear as inrolled tubes.

233. Double larkspur Compare with Fig. 208.

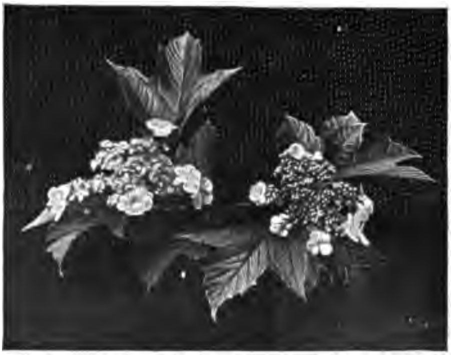
283. **ATTACHMENT OF THE FLOWER PARTS.**—The parts of the flower may all be borne directly on the torus, or one part may be borne on another. With reference to the pistil or ovary, the stamens and envelopes may be attached in three ways: **hypogynous,** all free and attached under the ovary, as in Fig. 187; **perigynous,** or attached to a more or less evident cup surrounding the ovary, as in Fig. 194; **epigynous,** some or all of them apparently borne on the ovary, as in Fig. 189.


234. Narcissus or daffodil. Single flower at the right; double flowers at the left.

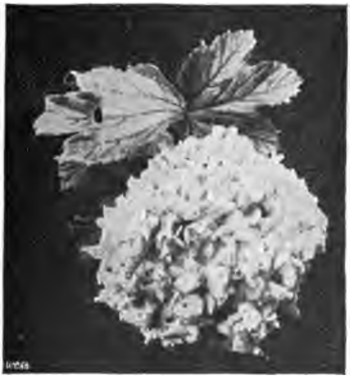

235. Petals arising from the staminal column of hollyhock; and accessory petals in the corolla-whorl.

284. **DOUBLE FLOWERS.** — Under the stimulus of cultivation and increased food-supply, flowers tend to become double. True doubling arises in two ways,

morphologically: (1) *stamens or pistils may change to petals* (Fig. 235); (2) *adventitious or accessory petals may arise in the circle of petals.* Both of these categories may be present in the same flower, as in Figs. 233, 234, and 235. In the full-double hollyhock, the petals derived from the staminal column are shorter and make a rosette in the center of the flower. Other modifications of flowers are sometimes known as doubling. For example, double dahlias (Fig. 232), chrysanthemums and sunflowers are forms in which the disk flowers have developed rays. The snowball is another case. In the wild plant (Fig. 236) the external flowers of the cluster are large and sterile. In the cultivated plant (Fig. 237) all the flowers have become large and sterile. Hydrangea is a similar case.

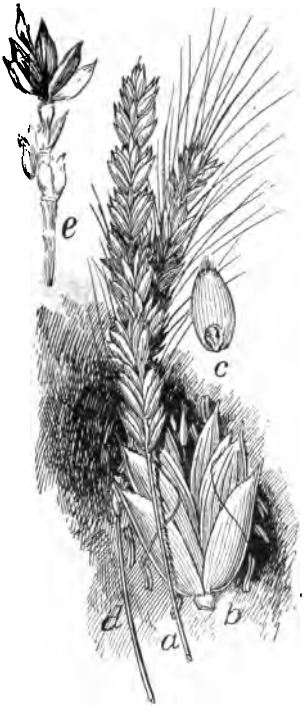


236. The wild or original form of the snowball.—Outer flowers larger.



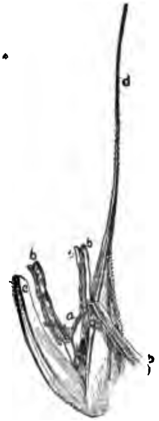
237. Cultivated snowball, in which all the flowers in the cluster have become large and showy.

REVIEW. — How do flowers vary in form? How are the various parts determined in disguised flowers? What are 5-merous and 3-merous flowers? What are some of the common forms of gamopetalous corollas? Describe a labiate flower. Personate. Lily flower. Papilionaceous flower. What are monadelphous and diadelphous stamens? Describe a mallow flower. Orchid flower. Spathaceous flower. Compositous flower. What do you understand by the terms hypogynous, perigynous, epigynous? How do flowers become double? What is meant by doubling in compositous flowers? In snowball and hydrangea?



238. Spikes and flowers of wheat. *a*. beardless wheat; *d*, bearded wheat; *b*, spikelet in bloom; *c*, grain; *e*, single spikelet on a mature head. The beards in *d* are awns on the flowering glumes.

NOTE.—The flowers of grasses are too difficult for the beginner, but if the pupil wishes to understand them he may begin with wheat or rye. The "head" or spike of wheat is made up of flowers and bracts. The flowers are in little clusters or *spikelets* (often called "breasts" by farmers). One of the spikelets is shown at *b*, in Fig. 238. Each spikelet contains from 1–4 flowers or florets. The structure of the flower is similar to that of rye (Fig. 239) and other grasses. The pistil has 2 feathery protruded stigmas (wind-pollinated) shown at *a*, Fig. 239. There are 3 stamens, *b*, *b*, *b*. There are minute scales in the base of the flower (not shown in the cut) which probably represent true floral envelopes. These are *lodicules*. The larger parts, *c*, *d*, are bracts. The larger one, *d*, is the *flowering glume*, and the smaller, *c*, is a *palet*. The entire spikelet is also subtended by two bracts or *glumes*; these are the two lowermost parts in *b*, Fig. 238. The glumes of the spikelet, and flowering glumes and palets of the flowers, constitute the chaff when wheat is threshed.



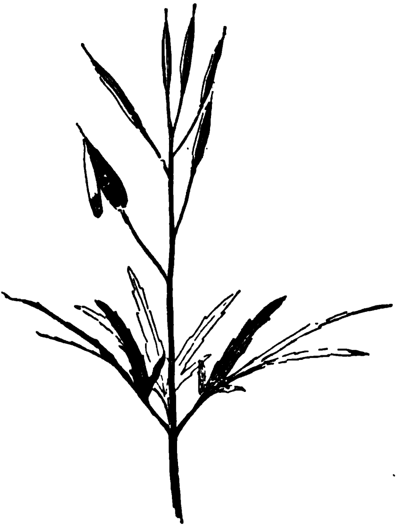
239. Flower of rye. *a*, stigma; *b*, *b*, *b*, stamens; *c*, palet; *d*, flowering glume.

CHAPTER XXI

FRUITS

285. The ripened ovary, with its attachments, is known as the **fruit.** *It contains the seeds.* If the pistil is simple, or of one carpel, the fruit also will have one compartment. If the pistil is compound, or of more than one carpel, the fruit usually has an equal number of compartments. The compartments in pistil and fruit are known as **locules** (from Latin *locus*, meaning "a place").

286. The simplest kind of fruit is a *ripened 1-loculed ovary.* The first stage in complexity is a ripened *2- or many-loculed ovary.* Very complex forms may arise by the *attachment of other parts to the ovary.* Sometimes the style persists and becomes a beak (mustard pods, dentaria, Fig. 240) or a tail as in clematis; or the calyx may be attached to the ovary; or the ovary may be imbedded in the receptacle, and ovary and receptacle together constitute the fruit; or an involucre may become a part of the fruit, as in the husk of the walnut and hickory, and cup of the acorn. The chestnut (Fig. 241) and the beech bear a prickly involucre, but the nuts, or true fruits, are not



240. Dentaria, or tooth-wort, in fruit.

grown fast to it, and the involucre can scarcely be called a part of the fruit. A ripened ovary is a **pericarp.** A pericarp to which other parts adhere, has been called an **accessory** or **reinforced fruit.**

241. Chestnuts are ripened ovaries. They are borne in a prickly involucre. The remains of the catkin of staminate flowers is seen in the picture.

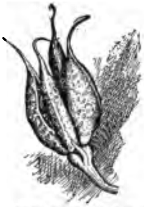
287. Some fruits are **dehiscent,** or split open at maturity(264) and liberate the seeds; others are **indehiscent,** or do not open. A dehiscent pericarp is called a **pod.** The parts into which such a pod breaks or splits are known as **valves.** In indehiscent fruits the seed is liberated by the decay of the envelope, or by the rupturing of the envelope by the germinating seed. Indehiscent winged pericarps are known as **samaras** or **key-fruits** (consult Chapter XXII). Maple, elm (Fig. 93), and ash (Fig. 127) are examples.

288. PERICARPS.—The simplest pericarp is a dry, one-seeded, indehiscent body. It is known as an **akene.** A head of akenes is shown in Fig. 242, and the structure is explained in Fig. 191. Akenes may be seen in buttercup, hepatica, anemone, smartweed, buckwheat.

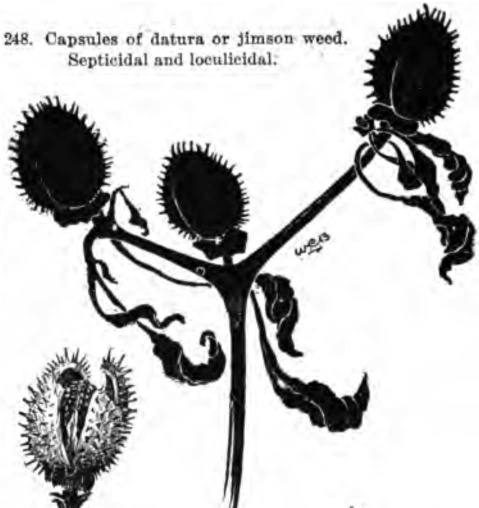
242. Akenes of buttercup.

289. A 1-loculed pericarp which dehisces along the front edge (that is, the inner edge, next the center of the flower) is a **follicle.** The fruit of the larkspur (Fig. 243) is a follicle. There are usually five of these fruits (sometimes three or four) in each larkspur flower, each pistil ripening into

243. Follicle of larkspur.



244. Young follicles of larkspur. Normally, the flower has 5 pistils, but some are lost in the struggle for existence.



248. Capsules of datura or jimson weed. Septicidal and loculicidal.

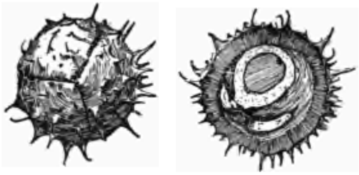
245. Follicles of swamp milkweed, not yet dehisced.

250. Apical dehiscence in capsule of bouncing Bet. Four columns of seeds are attached to a central shaft.

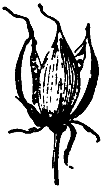
249. Capsules of evening primrose. Loculicidal.

246. Legumes of perennial or everlasting pea.

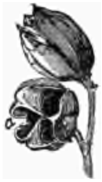
247. Legumes of Lima bean.



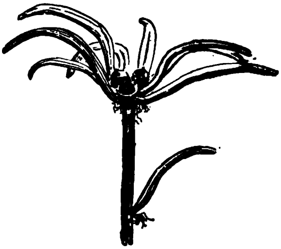
251. Three-carpelled fruit of horse-chestnut. Two locules are closing by abortion of the ovules.



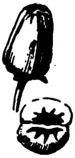
252. St. John's wort. Septicidal.



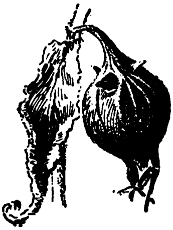
253. Loculicidal pod of day-lily.



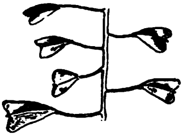
254. Pyxis of portulaca or rose-moss.



255. Toad-flax capsule.



256. Basal dehiscence of campanula capsule.



259. Shepherd's purse. Silicle.

257. Two-valved pods of catalpa.

258. Large 2-valved pods or capsules of tecoma or trumpet-creeper.

a follicle (Fig. 244). If these pistils were united, a single compound pistil would be formed. Columbine, peony, ninebark also have follicles; milkweed, also (Fig. 245).

260. Berries of the snowberry.

290. A 1-loculed pericarp which dehisces on both edges is a **legume.** Peas and beans are typical examples (Figs. 246, 247): in fact, this character gives name to the pea-family, — Leguminosæ. Often the valves of the legume twist forcibly and expel the seeds, throwing them some distance. The word pod is sometimes restricted to legumes, but it is better to use it generically (as in 287) for all dehiscent pericarps.

291. A compound pod—dehiscing pericarp of two or more carpels—is a **capsule** (Figs. 248, 249). There are some capsules of one locule, but they were compound when young (in the ovary stage) and the partitions have vanished (Fig. 250). Sometimes one or more of the carpels are uniformly crowded out by the exclusive growth of other carpels (Fig. 251). The seeds or parts which are crowded out are said to be *aborted.*

261. Eggplant fruits. Examples of large berries.

292. There are several ways in which capsules dehisce or open. When they break along the partitions (or septa), **the mode is known as septicidal dehiscence**; Fig. 252

shows it. In septicidal dehiscence the fruit separates into parts representing the original carpels. These carpels may still be entire, and they then dehisce individually, usually along the inner edge as if they were follicles. When the compartments split in the middle, between the partitions, the mode is **loculicidal dehiscence** (Fig. 253). In some cases the dehiscence is at the top, when it is said to be **apical** (although several modes of dehiscence are here included). When the whole top comes off, as in purslane and garden portulaca (Fig. 254) the pod is known as a **pyxis**. In some cases apical dehiscence is by means of a hole or clefts (Fig. 255). In pinks and their allies the dehiscence does not extend much below the apex (Fig. 250). Dehiscence may be **basal** (Fig. 256). Two-loculed capsules which resemble legumes in external appearance are those of catalpa and trumpet-creeper (Figs. 257, 258).

262. Plum; example of a drupe.

293. The peculiar capsule of the mustard family, or Cruciferæ, is known as a **silique** when it is distinctly longer than broad (Fig. 240), and a **silicle** when its breadth nearly equals or exceeds its length (Fig. 259). A cruciferous capsule is 2-carpelled, with a thin partition, each locule containing seeds in two rows. The two valves detach from below upwards. Cabbage, turnip, mustard, cress, radish, shepherd's purse, sweet alyssum, wallflower, honesty, are examples.

263. Aggregate fruits of raspberry.

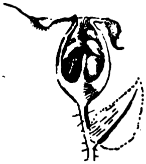
294. The pericarp may be *fleshy and indehiscent*. A pulpy pericarp with several or many seeds is a **berry** (Fig. 260). To the horticulturist a berry is a small, soft, edible fruit,

without particular reference to its structure. The botanical and horticultural conceptions of a berry are, therefore, unlike. In the botanical sense, gooseberries, currants, grapes, tomatoes, potato-balls and even eggplant fruits (Fig. 261) are berries; strawberries, raspberries, blackberries are not.

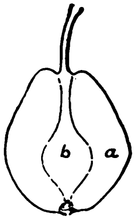
264. Strawberries. The edible part is torus.

295. A fleshy pericarp containing one relatively large seed or stone is a **drupe.** Examples are plum (Fig. 262), peach, cherry, apricot, olive. The walls of the pit in the plum, peach, and cherry are formed from the inner coats of the ovary, and the flesh from the outer coats. Drupes are also known as *stone fruits.*

296. Fruits which are formed by the subsequent union of separate pistils are **aggregate fruits.** The carpels in aggregate fruits are usually more or less fleshy. In the raspberry and blackberry flower, the pistils are essentially distinct, but as the pistils ripen they cohere and form one body. Fig. 263. Each of the carpels or pistils in the raspberry and blackberry is a little drupe, or **drupelet.** In the raspberry the entire fruit separates from the torus, leaving the torus on the plant. In the blackberry and dewberry the fruit adheres to the torus, and the two are removed together when the fruit is picked.



265. Hip of rose.



266. Diagram of a pear. The receptacle is *a*, and the pericarp *b*.

297. **ACCESSORY FRUITS.**—When the pericarp and some other part grow together, the fruit is said to be **accessory** or **reinforced** (286). An example

267. Apple flowers.

268. Young apple fruits.

is the strawberry (Fig. 264). The edible part is a greatly *enlarged torus*, and the pericarps are akenes imbedded in it. These akenes are commonly called seeds.

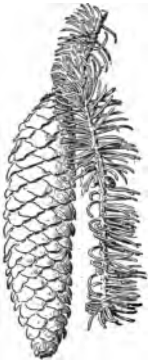
269. Pepo of squash.

298. Various kinds of reinforced fruits have received special names. One of these is the **hip**, characteristic of roses, Fig. 265. In this case, the torus is deep and hollow, like an urn, and the separate akenes are borne inside it. The mouth of the receptacle may close, and the walls sometimes become fleshy: the fruit may then be mistaken for a berry. The fruit of the pear, apple, and quince is known as a **pome**. In this case the five united carpels are completely buried in the hollow torus, and the torus makes most of the edible part of the ripe fruit, while the pistils are represented by the core (Fig. 266). Fig. 267 shows the apple in bloom; Fig. 268 shows young fruits, only one having formed in each cluster. In the lower lefthand flower of Fig. 267, note that the sepals do not fall. Observe the sepals on the top of the torus (apex of the fruit) in Fig. 268. In the plum flower (Fig. 194), note that the pistil sits free in the hollow torus: imagine the pistil and torus grown together, and something like a pome might result. The fruit of pumpkin, squash (Fig. 269), melon and cucumber is a **pepo**. The outer wall is torus, but the sepals do not persist, and the fruit is normally 3-loculed (although the partitions may disappear as the fruit ripens).

270. Winged seed of Norway spruce.

299. **GYMNOSPERMOUS FRUITS.** — In pines, spruces, and their kin, there is no fruit in the sense in which the word is used in the preceding pages, because there is no ovary. The ovules are naked or uncovered, in

the axils of the scales of the young cone, and they have neither style nor stigma. The pollen falls directly on the mouth of the ovule. The ovule ripens into a seed (Fig. 270) which is usually winged. Because the ovule is not borne in a sac or ovary, these plants are called **gymnosperms** (Greek for "naked seeds"). All the true cone-bearing plants are of this class; also certain other plants as red cedar, juniper, yew. The plants are monœcious or sometimes diœcious. The staminate flowers are mere naked stamens borne beneath scales, in small yellow catkins which soon fall. The pistillate flowers are naked ovules beneath scales on cones which persist (Figs. 271, 272).



271. Pistillate cone of Norway spruce. This tree is one of the commonest of planted evergreens.

272. Pistillate cone of white pine.

REVIEW.—What is a fruit, as understood by the botanist? What is a locule? What are simple, compound, and accessory or reinforced fruits? Define pericarp. Pod. What are dehiscent and indehiscent fruits? What is a samara or key-fruit? Define akene. Follicle. Legume. Capsule. Explain septicidal and loculicidal dehiscence. Apical dehiscence. Basal dehiscence. What is a pyxis? Silique? Silicle? Berry? Drupe? Drupelet? Explain an aggregate fruit. Explain the fruit of strawberry, rose, apple, squash. What is the fruit of pines and spruces?

NOTE.—Fully mature fruits are best for study, particularly if it is desired to see dehiscence. For comparison, pistils and partially grown fruits should be had at the same time. If the fruits are not ripe enough to dehisce, they may be placed in the sun to dry. In the school it is well to have a collection of fruits for study. The specimens may be kept in glass jars.

The following diagram will aid the pupil to remember some of the fruits to which particular names have been given. He must be warned, however, that the diagram does not express the order of evolution of the various kinds. He should also remember that there are many common fruits which answer to no definition, and these should be studied and compared with the forms which have received definite names.

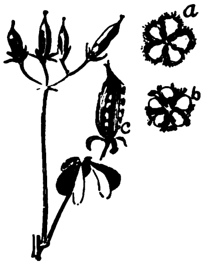
- PERICARPS
  - *Dry pericarps*
    - Simple
      - akene (indehiscent)
      - follicle (dehiscent)
      - legume (dehiscent)
    - Compound (capsule)
      - septicidal dehiscence
      - loculicidal dehiscence
      - apical dehiscence. [Pyxis.
  - *Fleshy pericarps*
    - berry
    - drupe
    - drupelet
  - *Aggregate pericarps*
- ACCESSORY FRUITS
  - strawberry
  - hip
  - pome
  - pepo
- GYMNOSPERMOUS OR CONE FRUITS

Autumn fruits.

CHAPTER XXII

DISPERSAL OF SEEDS

300. It is to the plant's advantage to have its seeds distributed as widely as possible. **It has a better chance of surviving in the struggle for existence.** It gets away from competition. Many seeds and fruits are of such character as to increase their chances of wide dispersal. The commonest means of dissemination may be classed under four heads: *explosive fruits; transportation by wind; transportation by birds; burs*



273. Explosive fruits of oxalis. An exploding pod is shown at *c*. The dehiscence is shown at *b*. The structure of the pod is seen at *a*.

301. **EXPLOSIVE FRUITS. — Some pods open with explosive force and scatter the seeds.** Even beans and everlasting peas (Fig. 246) do this. More marked examples are the locust, witch hazel, garden balsam, wild jewel weed or impatiens, violet, and the oxalis (Fig. 273). The oxalis is common in several species in the wild and in cultivation. One of them is known as wood-sorrel. Fig. 273 shows the common yellow oxalis. The pod opens loculicidally.

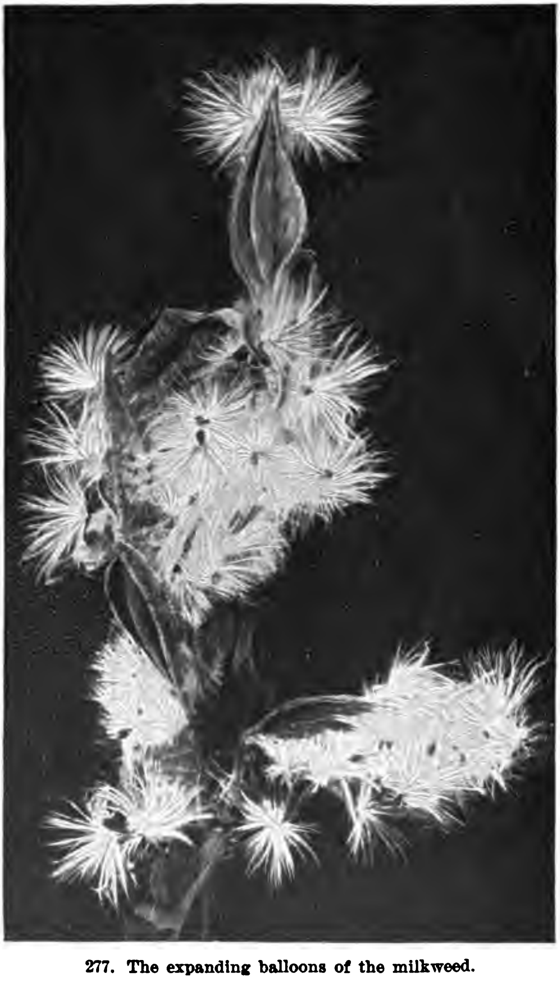
274. Winged seeds of catalpa.

275. Wind-blown fruits of dandelion.

The elastic tissue suddenly contracts when dehiscence takes place, and the seeds are thrown violently. The squirting cucumber is easily grown in a garden (procure seeds of seedsmen), and the fruits discharge the seeds with great force, throwing them many feet.

276. Thistle-down ready for a journey. In a gentle wind it rides high in the air.

302. **WIND-TRAVELERS.**— Wind-transported seeds are of two general kinds; — those which are provided with wings, as the flat seeds of catalpa (Fig. 274) and cone-bearing trees (Fig. 270) and the samaras of ash, elm,



277. The expanding balloons of the milkweed.

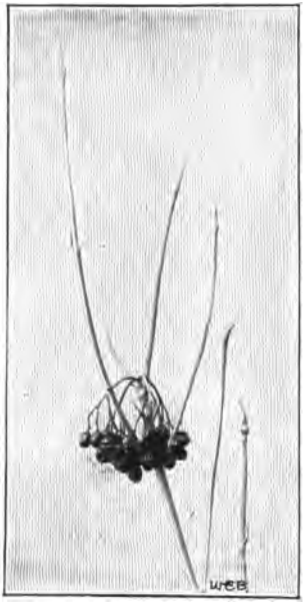
tulip-tree, ailanthus, and maple; those which have **feathery buoys or parachutes** to enable them to float in the air. Of the latter kind are the fruits of many composites, in which the pappus is copious and soft. Dandelion (Fig.

275) and thistle (Fig. 276) are examples. The silk of the milkweed (Fig. 277) has a similar office, and also the wool of the cat-tail (Fig. 278). Recall the cottony seeds of the willow and poplar.

303. DISPERSAL BY BIRDS.— **Seeds of berries and of other small fleshy fruits are carried far and wide by birds.** The pulp is digested, but the seeds are not injured. Note how the cherries, raspberries, blackberries, and Juneberries spring up in the fence-rows, where the birds rest. Some berries and drupes persist far into winter, when they supply food to cedar birds, robins, and the winter birds. Fig. 279. Red cedar is distributed by birds. Many of these pulpy fruits are agreeable as human food, and some of them have been greatly enlarged or "improved" by the arts of the cultivator. Consult paragraph 379 for the process by which such result may have been attained

278. The fruits of the cat-tail are carried in the late autumn winds.

304. BURS.— Many seeds and fruits bear spines, hooks, and hairs which **adhere to the coats of animals and to**



279. Drupes of the black haw, loved of robins in winter.

clothing. The burdock has an involucre with hooked scales, containing the fruits inside. Fig. 280. The clotbur is also an involucre. Both are compositous plants, allied to thistles, but the whole head, rather than the separate fruits, is transported. In some compositous fruits the pappus takes the form of hooks and spines, as in the "Spanish bayonets" and "pitchforks." Fruits of various kinds are known as "stick tights," as of the agrimony and hound's tongue. Those who walk in the woods in late summer and fall are aware that plants have means of disseminating themselves. Fig. 281. If it is impossible to identify the burs which one finds on clothing, the seeds may be planted and specimens of the plant may then be grown.

280. The cow is carrying burdocks.

Review. — What advantage is it to the plant to have its seeds widely dispersed? What are the leading ways in which fruits and seeds are dispersed? Name some explosive fruits. Describe wind-travelers. What seeds are carried by birds? Describe some bur with which you are familiar.

Note.—This lesson will suggest other ways in which seeds are transported. Nuts are buried by squirrels for food, but if they are not eaten they may grow. The seeds of many plants are blown on the snow. The old stalks of weeds, standing through the winter, may serve to disseminate the plant. Seeds are carried by water down the streams and along shores. About woollen mills strange plants often spring up from seed brought in the fleeces. Sometimes the entire plant is rolled for miles before the winds. Such plants are "tumble-weeds." Examples are Russian thistle (Fig. 99), hair-grass or tumble-grass (Panicum capillare), cyclone plant (Cycloloma platyphyllum), and white amaranth (Amaranthus albus). About seaports strange plants are often found, having been introduced in the earth that is used in ships for ballast. These plants are usuallv known as "ballast plants." Most of them do not persist long.

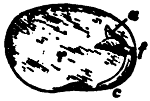
281. Stealing a ride.

A zinc-lined box may be fitted to the school-room window and used as a receptacle for plants. A faucet under one corner will drain off the accumulated water. Geranium, coleus, grevillea, some begonias, and other plants may be grown in the conditions which are present in most school-rooms. If the plants become sick, take them to the florist's.

CHAPTER XXIII

GERMINATION

305. **THE SEED.**—We have found (259) that by the process of fertilization a seed is formed. The seed contains a **miniature plant or embryo**. The embryo usually has three parts which have received names: the little stemlet or **caulicle**; the seed-leaf or **cotyledon** (usually 1 or 2); the bud or **plumule** lying between or above the cotyledons. These parts are well seen in the common bean (Fig. 282), particularly when the seed has been soaked for a few hours. One of the large cotyledons —comprising half of the bean—is shown at *r*. The caulicle is at *c*. The plumule is at *a*. The cotyledons are attached to the caulicle at *f*: *this point is the first node, and the plumule is at the second node.*



282. Parts of the bean. *r*, cotyledon; *c*, caulicle; *a*, plumule; *f*, first node.

306. Every seed is **provided with food**, to support the germinating plant. Commonly this food is starch. The food may be stored *in the cotyledons*, as in bean, pea, squash; or *outside the cotyledons*, as in castor bean, pine, Indian corn. When the food is around the embryo, it is usually called **endosperm.**

307. The embryo and endosperm are inclosed within a covering made of two or more layers and known as the **seed-coats.** Over the point of the caulicle is a minute hole or a thin place in the coats known as the **micropyle.** This is the point at which the pollen-tube entered the forming ovule and through which the caulicle breaks in germination. The micropyle is shown at *m* in Fig. 283. The scar where the seed broke from its funiculus or stalk

is the **hilum.** It occupies a third of the length of the bean in Fig. 283. The hilum and micropyle are always present in seeds, but they are not always close together. In many cases it is difficult to identify the micropyle in the dormant seed, but its location is at once shown by the protruding caulicle as germination begins. Opposite the micropyle in the bean (at the other end of the hilum) is an elevation known as the raphe. This is formed by a union of the funiculus or seed-stalk with the seed-coats and through it food was transferred for the development of the seed, but it is now functionless.

283. External parts of bean.

308. Seeds differ wonderfully in size, shape, color, and other characteristics. They also vary in longevity. These characteristics are **peculiar to the species or kind.** Some seeds maintain life only a few weeks or even days, whereas others will "keep" for ten or twenty years. In special cases, seeds have retained vitality longer than this limit, but the stories that live seeds, several thousand years old, have been taken from mummies are unfounded.

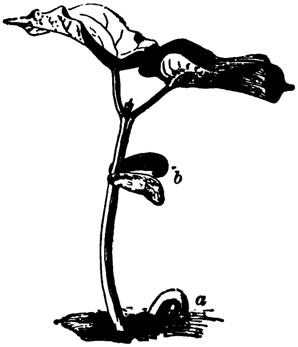
309. **GERMINATION.**—The embryo is not dead: it is only dormant. *When supplied with moisture, warmth, and oxygen (air), it awakes and grows: this growth is* **germination.** The embryo lives for a time on the stored food, but gradually the plantlet secures a foothold in the soil and gathers food for itself. *When the plantlet is finally able to shift for itself, germination is complete.*

310. The germinating seed first *absorbs water, and swells.* The starchy matters gradually become soluble. The seed-coats are ruptured, the caulicle and plumule emerge. During this process the seed **respires freely,** *throwing off carbon dioxid* (CO_2). Fill a tin box or large-necked bottle with dry beans or peas, then add water; note how much they swell. Secure two fruit-jars. Fill one of them a third full of beans and keep them moist. Allow the

other to remain empty. In a day or two insert a lighted splinter or taper into each. In the empty jar the taper burns: it contains oxygen. In the seed jar the taper goes out: the air has been replaced by carbon dioxid. Usually there is a perceptible rise in temperature in a mass of germinating seeds.

284. The young roots are not able to gain a foothold.

311. The caulicle usually elongates, and from its lower end roots are emitted. The elongating caulicle is known as the **hypocotyl** ("below the cotyledons"). That is, the hypocotyl is that part of the stem of the plantlet lying between the roots and the cotyledon. *The general direction of the young hypocotyl or emerging caulicle is downwards.* As soon as roots form it becomes fixed, and its subsequent growth tends to raise the cotyledons above the ground, as in the bean. When cotyledons rise into the air, germination is said to be **epigeal** ("above the earth"). Bean and pumpkin are examples. When the hypocotyl does not elongate greatly and the cotyledons remain under ground, the germination is **hypogeal** ("beneath the earth"). Pea and scarlet runner bean are examples. When the germinating seed lies on a hard surface, as on closely compacted soil, the hypocotyl and rootlets may not be able to secure a foothold



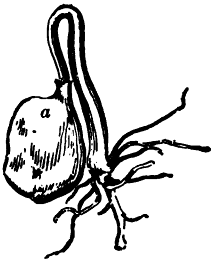
286. Germination of bean.

285. Cotyledons of germinating bean spread apart to show elongating caulicle and plumule.

and they assume grotesque forms. Fig. 284. Try this with peas and beans.

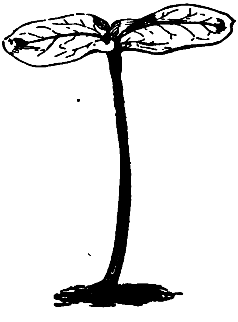
312. The first internode above the cotyledons — between the cotyledons and the plumule — is the **epicotyl**. It elevates the plumule into the air, and *the plumule-leaves expand into the first true leaves of the plant*. These first true leaves, however, may be very unlike the later leaves.

287. Sprouting of castor bean.

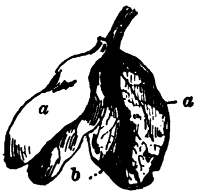


288. Germination of castor bean. Endosperm at *a*.

313. **GERMINATION OF BEAN.** — The common bean, as we have seen (Fig. 282) has cotyledons which occupy all the space inside the seed-coats. When the hypocotyl or elongating caulicle emerges, the plumule-leaves have begun to enlarge and to unfold (Fig. 285). The hypocotyl elongates rapidly. One end of it is held by the roots. The other is held by the seed-coats in the soil. It, therefore, takes the form of a loop, and its central part "comes up" first (*a*, Fig. 286). Presently it draws the cotyledons out of the seed-coats, and then it straightens and the cotyledons expand. These cotyledons or "halves of the bean," persist for some time, (*b*, Fig. 286). They often become green and probably perform some function of foliage. Because of its large size, Lima bean shows all these parts well.



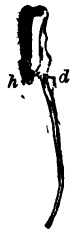
290. Germination complete in castor bean



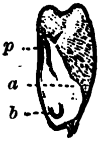
289. Castor bean. Endosperm at *a*, *a*; cotyledons at *b*.

314. **GERMINATION OF CASTOR BEAN.** — In the castor bean the hilum and micropyle are at the smaller end (Fig.

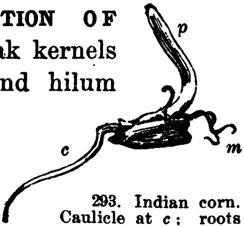
287). The bean "comes up" with a loop, which indicates that the hypocotyl greatly elongates. On examining a germinating seed, however, it will be found that the cotyledons are contained inside a fleshy body or sac (*a*, Fig. 288). This sac is the endosperm. To its inner surface the thin, veiny cotyledons are very closely appressed, absorbing its substance (Fig. 289). The cotyledons increase in size as they reach the air (Fig. 290), and become functional leaves.



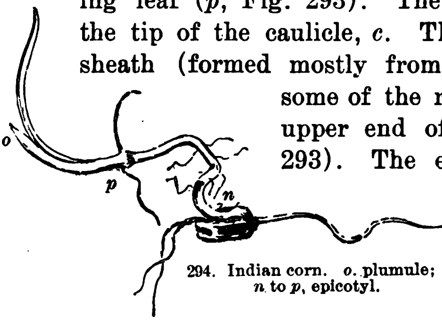
291. Sprouting Indian corn. Hilum at *h*; micropyle at *d*.



292. Kernel of Indian corn. Caulicle at *b*; cotyledon *a*; plumule *p*.



293. Indian corn. Caulicle at *c*; roots emerging at *m*; plumule at *p*.



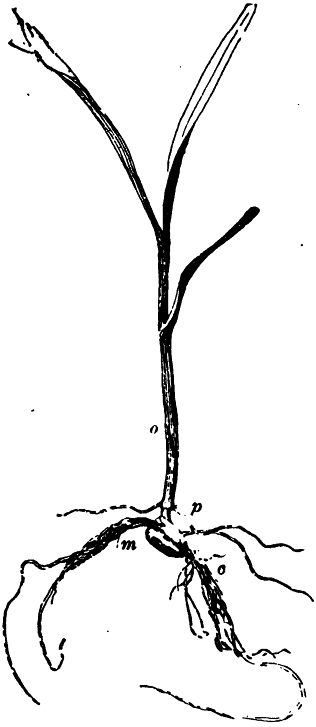
294. Indian corn. *o*, plumule; *n* to *p*, epicotyl.

315. **GERMINATION OF INDIAN CORN.**—Soak kernels of corn. Note that the micropyle and hilum are at the smaller end (Fig. 291). Make a longitudinal section through the narrow diameter; Fig. 292 shows it. The single cotyledon is at *a*, the caulicle at *b*, the plumule at *p*. The cotyledon remains in the seed. The food is stored both in the cotyledon and as endosperm, chiefly the latter. The emerging shoot is the plumule, with a sheathing leaf (*p*, Fig. 293). The root is emitted from the tip of the caulicle, *c*. The caulicle is held in a sheath (formed mostly from the seed-coats), and some of the roots escape through the upper end of this sheath (*m*, Fig. 293). The epicotyl elongates, particularly if the seed is planted deep or if it is kept for some time confined. In Fig. 294 the epicotyl has elongated from *n* to *p*. The true plumule-leaf is at *o*, but other leaves grow from its sheath. In Fig. 295 the roots

are seen emerging from the two ends of the caulicle-sheath, *c*, *m*; the epicotyl has grown to *p*; the first plumule-leaf is at *o*.

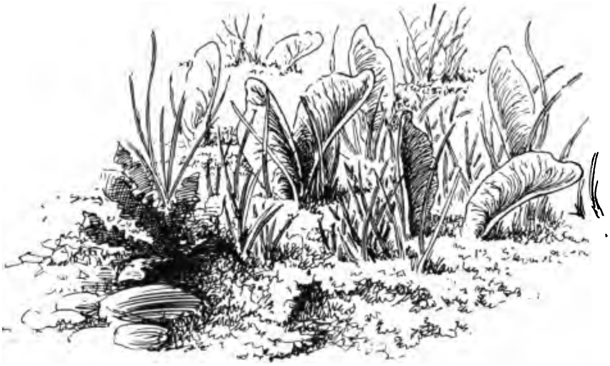
Review.—What does a seed contain? What do you understand by the embryo? What are its parts? Where is the food in the seed? What are the seed-coats? What is the micropyle? Hilum? How may the position of the micropyle be determined? How do seeds differ? With what are these differences associated? What is germination? Under what conditions does a seed germinate? When is germination complete? What is the first phenomenon of germination? Explain the relation to O and CO_2. Define hypocotyl. Epicotyl. Hypogeal and epigeal germination. What becomes of the plumule? Explain germination in a seed which you have studied.

Note.—Few subjects connected with the study of plant-life are so useful in school-room demonstrations as germination. The pupil should prepare the soil, plant the seeds, water them, and care for the plants. Plant in pots or shallow boxes. Cigar-boxes are excellent. The depth of planting should be two to three times the diameter of the seeds. It is well to begin the planting of seeds at least ten days in advance of the lesson, and to make four or five different plantings at intervals. A day or two before the study is taken up, put seeds to soak in moss or cloth. The pupil then has a series from swollen seeds to complete germination, and all the steps can be made out. Dry seeds should be had for comparison.

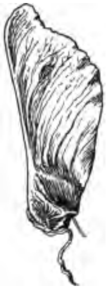


295. Germination is complete. *p*, top of epicotyl; *o*, plumule-leaf; *m*, roots; *c*, lower roots.

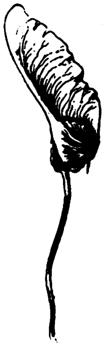
Good seeds for study are those detailed in the lesson,—bean, castor bean, corn. Make drawings and notes of all the events in the



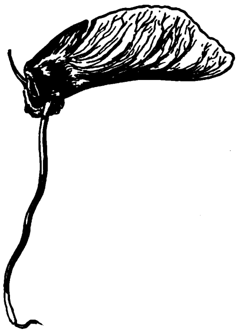
296. Natural planting of the fruits of Norway maple.



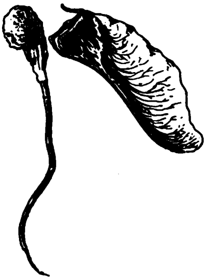
297. The beginning.



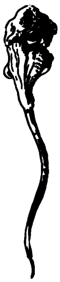
298. A later stage.



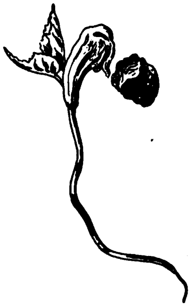
299. Another position.



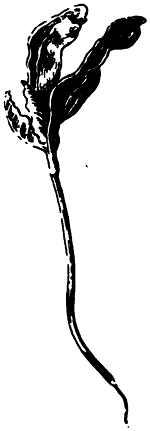
300. The wing cast off; the seed-coats still adhering.



301. Casting the seed-coats.



302. Free from the seed-coats.

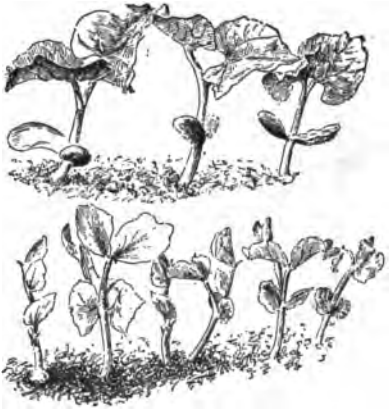


303. Free.

germination. Note the effects of unusual conditions, as planting too deep and too shallow and different sides up. For hypogeal germination, use the garden pea, scarlet runner or Dutch case-knife bean, acorn, horse-chestnut. Squash seeds are excellent for germination studies, because the cotyledons become green and leafy and germination is rapid. Its germination, as also that of the scarlet runner bean, is explained in "Lessons with Plants." Onion is excellent, except that it germinates too slowly. In order to study the root development of germinating plantlets, it is well to provide a deeper box with a glass side against which the seeds are planted.

Observe the germination of any seed which is common about the premises. Where elms and maples are abundant, the germination of their seeds may be studied in lawns and along fences. Figs. 296 to 303 suggest observations on the Norway maple, which is a common ornamental tree.

When studying germination, the pupil should note the differences in shape between cotyledons and plumule-leaves and between plumule-leaves and the normal leaves of the plant. Fig. 143. Make drawings.



Germination of beans and peas.

CHAPTER XXIV

PHENOGAMS AND CRYPTOGAMS

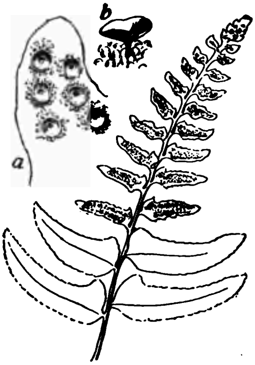
316. The plants thus far studied produce flowers; and the flowers produce **seeds** by means of which the plant is propagated. There are other plants, however, which produce no seeds, and these plants are more numerous than the seed-bearing plants. These plants propagate by means of **spores,** *which are usually simple generative cells containing no embryo.* These spores are very small, and sometimes are not visible to the naked eye.

317. Prominent amongst the spore-propagated plants are ferns. The common Christmas fern (so-called because it remains green during winter) is shown in Fig. 304. The plant has no trunk. The leaves spring directly from the ground. The leaves of ferns are called **fronds.** They vary in shape, as other leaves do. Compare Fig. 125 and the pictures in this chapter. Some of the fronds are seen to be narrower at the top. If these are examined more closely (Fig. 305) it will be seen that the leaflets are contracted and are densely covered beneath with brown bodies. These bodies are collections of **sporangia** or **spore-cases.**

304. Christmas fern.—Dryopteris acrostichoides; known also as Aspidium.

318. The sporangia are collected into little groups, known as **sori** (singular, sorus) or **fruit-dots.** Each sorus is covered with a thin scale or shield, known as an

indusium. This indusium separates from the frond at its edges, and the sporangia are exposed. Not all ferns have indusia. The polypode (Figs. 306, 307) does not: the sori are naked. In the brake (Fig. 308) and maiden-hair (Fig. 309) the edge of the frond turns over and forms an indusium. In some ferns (Fig. 310) an entire frond becomes contracted to cover the sporangia. In other cases the indusium is a sac-like covering, which splits (Fig. 311).

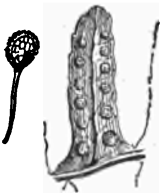


305. Fruiting frond of Christmas fern. Sori at *a*. One sorus with its indusium, at *b*.

319. The sporangium or spore-case of a fern is a more or less globular body and usually with a stalk (Fig. 307). *It contains the spores.* **When ripe it bursts and the spores are set free.** Lay a mature fruiting frond of any fern on white paper, top side up, and allow it to remain in a dry, warm place. The spores will discharge on the paper.

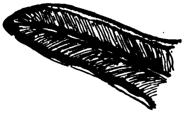
320. In a moist, warm place *the spores germinate.* They produce a small, flat, thin, green, more or less heart-shaped membrane (Fig. 312). This is the **prothallus.** Sometimes the prothallus is an inch or more across, but oftener it is less than one-fourth this size. It is commonly unknown except to botanists. Prothalli may often be found in greenhouses where ferns are grown. Look on the moist stone or brick walls, or

306. Common polypode fern.—Polypodium vulgare.



307. Sori and sporangium of polypode.

on the firm soil of undisturbed pots and beds. Or spores may be sown in a damp, warm place.



308. The brake fruits underneath the revolute edges of the leaf.

321. On the under side of the prothallus two kinds of organs are borne. These are the **archegonium** and the **antheridium.** These organs are minute specialized parts of the prothallus. Their positions on a particular prothallus are shown at *a* and *b* in Fig. 312, but in some ferns they are on separate prothalli (plant diœcious). *The sperm-cells escape from the antheridium and in the water which collects on the prothallus are carried to the archegonium, where fertilization takes place.* From a fertilized archegonium a plant grows, and this plant becomes the "fern." In most cases the prothallus dies soon after the fern plant begins to grow.

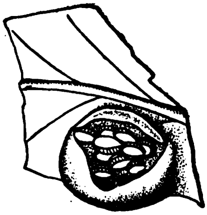
322. The fern plant, arising from the fertilized egg in the archegonium, becomes a perennial plant, each year producing spores from its fronds, as we have seen; but these spores—which are merely detached special kinds of cells—produce the prothallic phase of the fern plant, from which new individuals arise. *A fern is fertilized but once in its lifetime.* This alternation of phases is called the **alternation of generations.** The first or fertilized plant is the **gametophyte**; the second or non-fertilized plant is the **sporophyte** (*phyton* is Greek for "plant").

309. Reflexed margins of a maidenhair frond.

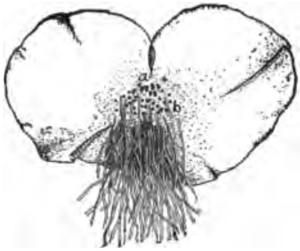
323. The alternation of generations runs all through the vegetable kingdom, although there are some groups of plants in which it is very obscure or apparently want-

ing. It is very marked in ferns and mosses. In algæ (including the seaweeds) the gametophyte makes the "plant," as the non-botanist knows it. *There is a general tendency, in the evolution of the vegetable kingdom, for the gametophyte to lose its relative importance and for the sporophyte to become larger and more highly developed.* In the seed-bearing plants the sporophyte generation is the only one seen by the non-botanist. The gametophyte stage is of short duration and the parts are small: it is confined to the time of fertilization.

310. Fertile and sterile fronds of the sensitive fern.


311. A sac-like indusium.

324. The sporophyte of seed-plants, or the "plant" as we know it, produces spores — one kind being called **pollen-grains** and the other kind **embryo-sacs.** The pollen-spores are borne in sporangia, which are united into what are called *anthers*. The embryo-sac, which contains the egg-cell, is borne in a sporangium known as an *ovule*. A gametophytic stage is present in both pollen and embryo-sac: fertilization takes place, and a sporophyte arises. Soon this sporophyte becomes dormant, and is then known as an *embryo*. The embryo is packed away within tight-fitting coats, and the entire body is the *seed*. When the conditions are right the seed grows, and the sporophyte grows into herb, bush, or tree. The utility of the alternation of generations is not understood.



312. Prothallus of a fern. Enlarged. Archegonia at *a*; antheridia at *b*.

325. It happens that the spores of seed-bearing plants are borne amongst a mass of specially developed leaves known as *flowers:* therefore these plants have been known as the *flowering plants.* Some of the leaves are developed as envelopes (calyx, corolla), and others as spore-bearing parts, or *sporophylls* (stamens, pistils). But the spores of the lower plants, as of ferns and mosses, may also be borne in specially developed foliage, so that the line of demarcation between flowering plants and flowerless plants is not so definite as was once supposed. The one definite distinction between these two classes of plants is the fact that one class produces seeds and the other does not. The seed-plants are now often called *spermaphytes*, but there is no single coördinate term to set off those which do not bear seeds. It is quite as well, for popular purposes, to use the old terms, **phenogams** for the seed-bearing plants and **cryptogams** for the others. These terms have been objected to in recent years because their etymology does not express literal facts (*phenogam* refers to the fact that the flowers are showy, and *cryptogam* to the fact that the parts are hidden), but the terms represent distinct ideas in classification. Nearly every word in the language has grown away from its etymology. The cryptogams include three great series of plants—the Thallophytes or algæ, lichens and fungi, the Bryophytes or moss-like plants, the Pteridophytes or fern-like plants. In each of these series there are many families. See Chapter XXV.

REVIEW.—What is a spore? Describe the appearance of some fern plant which you have studied. What are the spores and sporangia? What is a sorus? Indusium? What grows from the spore? How does the new "fern" plant arise? What is meant by the phrase "alternation of generations"? Define gametophyte and sporophyte. Describe the alternation in flowering plants. Explain the flower from this point of view. What is the significance of the word spermaphyte? Contrast phenogam and cryptogam.

Note.—All the details of fertilization and of the development of the generations are omitted from this book, because they are subjects for specialists and demand more training in research methods than the high-school pupil can properly give to plant study. Cryptogams are perhaps as many as phenogams, and for this reason it has been urged that they are most proper subjects for study in the school. This position is untenable, however, for the best plant subjects for youth are those which mean most to his life. It is said, also, that they are best for the beginner because their life-processes are relatively simple in many cases; but the initial study of plants should be undertaken for the purpose of quickening the pupil's perception of common and familiar problems rather than for the purpose of developing a technical knowledge of a given science.

Tree ferns are inhabitants of the tropics.
They are often grown in choice greenhouses.

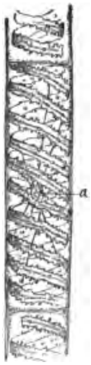
CHAPTER XXV

STUDIES IN CRYPTOGAMS

The special advanced pupil who has acquired skill in the use of the compound microscope, may desire to make more extended excursions into the cryptogamous orders. The following plants, selected as examples in various groups, will serve as a beginning.

ALGÆ

The algæ comprise most of the green floating "scum" which covers the surface of ponds and other quiet waters. The masses of plants are often called "frog spittle." Others are attached to stones, pieces of wood, and other objects submerged in streams and lakes, and many are found on moist ground and on dripping rocks. Aside from these, all the plants commonly known as seaweeds belong to this category. They are inhabitants of salt water.

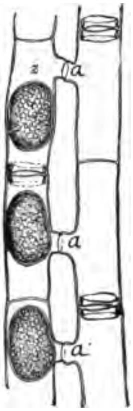


313. Strand of spirogyra, showing the chlorophyll bands. There is a nucleus at *a*.

The simplest forms of algæ consist of a single spherical cell, which multiplies by repeated division or fission. Most of the forms found in fresh water are filamentous, i. e., the plant-body consists of long threads, either simple or branched. Such a plant-body is termed a *thallus*. This term applies to the vegetative body of all plants which are not differentiated into stem and leaves. Such plants are known as *thallophytes* (325). All algæ contain chlorophyll, and are able to assimilate carbon dioxid from the air. This distinguishes them from the fungi.

Spirogyra.—One of the most common forms of the green algæ is spirogyra (Fig. 313). This plant usually forms the greater part of the floating green mass on ponds. The filamentous character of the thallus can be seen with the naked eye or with a hand-lens, but to study it carefully a microscope magnifying two hundred diameters or more should be used. The thread is divided into long cells by cross-walls which, according to the species, are either straight or curiously folded (Fig. 314). The chlorophyll is arranged in beautiful spiral bands near the wall of each cell. From the character of these bands the plant takes its name. Each cell is provided with a *nucleus* and other *protoplasm*. The nucleus is suspended near the center of the cell, *a*, Fig. 313, by delicate strands of protoplasm radiating toward the wall and terminating at certain points in the chlorophyll band. The remainder of the protoplasm forms a thin layer lining the wall. The interior of the cell is filled with cell-sap. The protoplasm and nucleus cannot be easily seen, but if the plant is stained with a dilute alcoholic solution of eosin (146) they become clear.

Spirogyra is propagated vegetatively by the breaking off of parts of the threads, which continue to grow as new plants. Resting-spores, which may remain dormant for a time, are formed by a process known as *conjugation*. Two threads lying side by side send out short projections, usually from all the cells of a long series (Fig. 314). The projections or processes from opposite cells grow toward each other, meet and fuse, forming a connecting tube between the cells. The protoplasm, nucleus, and chlorophyll band of one cell now pass through this tube, and unite with the contents of the other cell. The entire mass then becomes surrounded by a thick cellulose wall, thus completing the *resting-spore*, or *zygospore* (Fig. 314, *z*).

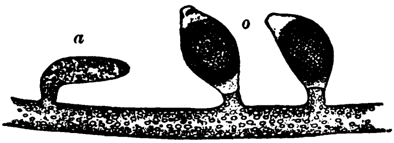


314. Conjugation of spirogyra. Ripe zygospores on the left; *a*, connecting tubes.

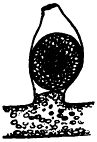
Vaucheria is another alga common in shallow water and on damp soil. The thallus is much branched, but the threads are not divided by cross-walls as in spirogyra. The plants are attached by means of colorless root-like organs which are much like the root-hairs of the higher plants: these are *rhizoids*. The chlorophyll is in the form of grains scattered through the thread.

Vaucheria has a special mode of vegetative reproduction by means of swimming spores or *swarm-spores*. These are formed singly in a short, enlarged lateral branch known as the *sporangium*. When the sporangium bursts the entire contents escape, forming a single large swarm-spore, which swims about by means of numerous lashes or cilia on its surface. The swarm-spores are so large that they can be seen with the naked eye. After swimming about for some time they come to rest and germinate, producing a new plant.

The formation of resting-spores of vaucheria is accomplished by means of special organs, *oögonia* Fig. 315. *o*, and *antheridia* Fig. 315, *a*. Both of these are specially developed branches from the thallus. The antheridia are nearly cylindrical, and curved toward the oögonia. The upper part of an antheridium is cut off by a cross-wall, and within it numerous ciliated *sperm-cells* are formed. These escape by the ruptured apex of the antheridium. The oögonia are more enlarged than the antheridia and have a beak-like projection turned a little to one side of the apex. They are separated from the thallus-thread by a cross-wall, and contain a single large green cell, the *egg-cell*. The apex of the oögonium is dissolved, and through the opening the sperm-cells enter. Fertilization is thus accomplished. After fertilization the egg-cell becomes invested with a thick wall and is thus converted into a resting-spore, the *oöspore* (Fig. 316).



315. Thread of vaucheria with oögonia and antheridia.



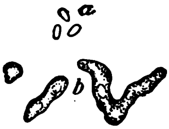
316. Ripe oöspore of vaucheria.

FUNGI

Some forms of fungi are familiar to every one. Mushrooms and toadstools, with their varied forms and colors, are common in fields, woods, and pastures. In every household the common moulds are familiar intruders, appearing on old bread, vegetables, and even within tightly sealed fruit jars, where they form a felt-like layer dusted over with blue, yellow, or black powder (181). The strange occurrence of these plants long mystified people, who thought they were productions of the dead matter upon which they grew, but now we know that a mould, like any other plant, cannot originate spontaneously; it must start from something which is analogous to a seed. The "seed" in this case is a *spore*. The term spore is applied to the minute reproductive bodies of all flowerless plants. A spore is a very simple structure, usually of only one plant cell, whose special function is to reproduce the plant. A spore may be produced by a vegetative process (growing out from the ordinary plant tissues), or it may be the result of a fertilization process (316).

317. Mucor mucedo, showing habit.

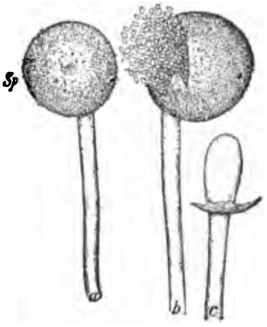
Mould.—One of these moulds, Mucor mucedo, which is very common on all decaying fruits and vegetables, is shown in Fig. 317, somewhat magnified. When fruiting, this mould appears as a dense mass of long white hairs, often over an inch high, standing erect from the fruit or vegetable upon which it is growing.



318. Spores of mucor; some germinating.

The life of this mucor begins with a minute rounded spore (*a*, Fig. 318), which lodges on the decaying material. When the spore germinates, it sends out a delicate thread which grows rapidly in length and forms very many branches which soon permeate every part of the substance on which the plant grows (*b*, Fig. 318). One of these threads is termed a hypha. All the threads together form the *mycelium* of the fungus (180). The mycelium disorganizes the material in which it grows, and thus nourishes the mucor plant (Fig. 317). It corresponds physiologically to the roots and stems of other plants.

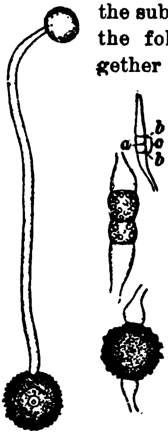
When the mycelium is about two days old it begins to form the long fruiting stalks which we first noticed. To study them, use a compound microscope magnifying about two hundred diameters. One of the stalks, magnified, is shown in Fig. 319, *a*. It consists of a rounded head, the sporangium, *sp*, supported on a long, delicate stalk, the *sporangiophore*, *st*. The stalk is separated from the sporangium by a wall which is formed at the base of the sporangium. This wall, however, does not extend straight across the thread, but it arches up into the sporangium like an inverted pear. It is known as the *columella*, *c*. When the sporangium is placed in water, the wall immediately dissolves and allows hundreds of spores, which were formed in the cavity within the sporangium, to escape, *b*. All that is left of the fruit is the stalk, with the pear-shaped columella at its summit, *c*. The spores which have been set free by the breaking of the sporangium wall are now scattered by the wind and other agents. Those which lodge in favorable places begin to grow immediately and reproduce the fungus. The others soon perish.



319. Mucor. *a*, sporangium; *b*, sporangium bursting; *c*, columella.

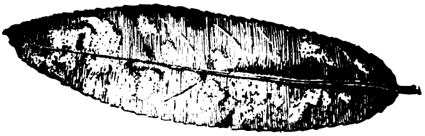
The mucor may continue to reproduce itself in this way indefinitely, but these spores are very delicate and usually die if they do not fall on favorable ground, so that the fungus is provided with another means of carrying itself over unfavorable seasons, as winter. This is accomplished by means of curious thick-walled resting-spores or zygospores. The zygospores are formed on the mycelium buried within the substance on which the plant grows. They originate in the following manner: Two threads which lie near together send out short branches, which grow toward each other and finally meet (Fig. 320). The walls at the ends, *a*, then disappear, allowing the contents to flow together. At the same time, however, two other walls are formed at points farther back, *b*, *b*, separating the short section, *c*, from the remainder of the thread. This section now increases in size and becomes covered with a thick, dark brown wall ornamented with thickened tubercles. The zygospore is now mature and, after a period of rest, it germinates, either producing a sporangium directly or growing out as mycelium.

The zygospores of the mucors form one of the most interesting and instructive objects among the lower plants. They are, however, very difficult to obtain. One of the mucors, Sporodinia grandis, may be frequently found in summer growing on toadstools. This plant usually produces zygospores, which are formed on the aërial mycelium. The zygospores are large enough to be recognized with a hand-lens. The material may be dried and kept for winter study, or the zygospores may be prepared for permanent microscopic mounts in the ordinary way.



320. Mucor showing formation of zygospore on the right; germinating zygospore on the left.

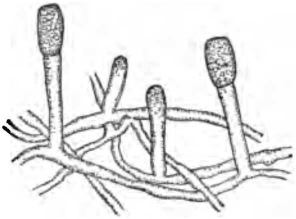
Willow mildew.—Most of the moulds are saprophytes (181). There are many other fungi which are parasitic on living plants and animals. Some of them have interesting and complicated life-histories, undergoing many changes before the original spore is again produced. The willow mildew and the common rust of wheat will serve to illustrate the habits of parasitic fungi.



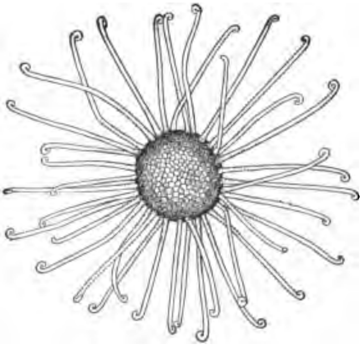
321. Colonies of willow mildew.

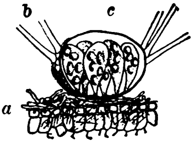
The willow mildew, Uncinula salicis, forms white downy patches on the leaves of willows (Fig. 321). These patches consist of numerous interwoven threads which may be recognized as the mycelium of the fungus. The mycelium in this case lives on the surface of the leaf and nourishes itself by sending short branches into the cells of the leaf to absorb food-materials from them.

Numerous *summer-spores* are formed on short erect branches all over the white surface. One of these branches is shown in Fig. 322. When it has grown to a certain length, the upper part begins to segment or divide into spores which fall and are scattered by the wind. Those falling on other willows reproduce the fungus there.


322. Summer-spores of willow mildew.

This process continues all summer, but in the later part of the season provision is made to maintain the mildew through the winter. If some of the white patches are closely examined in July or August, a number of little black bodies will be seen among the threads. These little bodies are called *perithecia,* shown in Fig. 323. To the naked eye they appear as minute specks, but when seen under a magnification of 200 diameters they present a very interesting appearance. They are hollow spherical bodies decorated around the outside with a fringe of crook-like hairs. The resting-spores of the willow mildew are produced in sacs or *asci* inclosed within the leathery perithecia. Fig. 324 shows a cross-section of a perithecium with the asci arising from the bottom. The spores remain securely packed in the perithecia. They do not ripen in the autumn but fall to the ground with the leaf and there remain securely protected among the dead foliage. The following spring they mature and are liberated by the decay of the perithecia. They are then ready to attack the unfolding leaves of the willow and repeat the work of the summer before.


323. Perithecium of willow mildew.



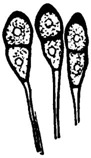
324. Section through perithecium of willow mildew.

Wheat rust.—The development of some of the rusts, like the common wheat rust (Puccinia graminis), is even more interesting and complicated than that of the mildews. Wheat rust is also a true parasite, affecting wheat and a few other grasses. The mycelium here cannot be seen by the unaided eye, for it consists of threads which are present within the host plant, mostly in the intercellular spaces. These threads also send short branches, or haustoria (180), into the neighboring cells to absorb nutriment.

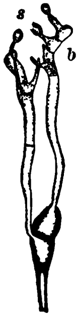
325. Sori containing teleutospores of wheat rust.

The resting-spores of wheat rust are produced in late summer, when they may be found in black lines breaking through the epidermis of the wheat-stalk. They are formed in masses, called *sori* (Fig. 325), from the ends of numerous crowded mycelial strands just beneath the epidermis of the host. The individual spores are very small and can be well studied only with high powers of the microscope (× about 400). They are brown two-celled bodies with a thick wall (Fig. 326). Since they are the resting- or winter-spores, they are termed *teleutospores* ("completed spores"). They usually do not fall, but remain in the sori during winter. The following spring each cell of the teleutospore puts forth a rather stout thread, which does not grow more than several times the length of the spore and terminates in a blunt extremity (Fig. 327). This germ-tube, or *basidium*, now becomes divided into four cells by cross-walls, which are formed from the top downwards. Each cell gives rise to a short, pointed branch which, in the course of a few hours, forms a single small spore at its summit. In Fig. 327 a germinating spore is drawn to show the basidium, *b*, divided into four cells, each producing a short branch with a little spore, *s*.

A most remarkable circumstance in the life-history of the wheat rust is the fact that the mycelium produced by the teleutospore can live only in barberry leaves, and it follows that if no barberry bushes are in the neighborhood the teleutospores finally perish. Those which happen to lodge on a barberry bush germinate immediately, producing a mycelium which enters the barberry leaf and grows within its tissues. Very soon the fungus produces a new kind of spores on the barberry leaves. These are

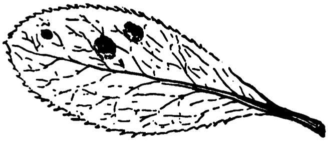


326. Teleutospore of wheat rust.



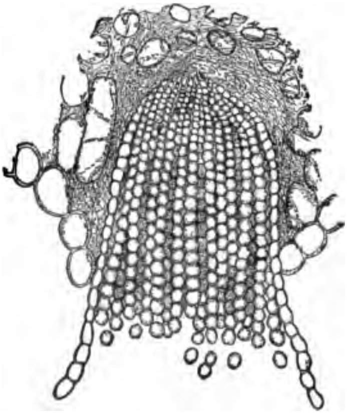
327. Germinating teleutospore of wheat rust.

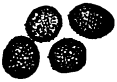
called *æcidiospores*. They are formed in long chains in little fringed cups, or *æcidia*, which appear in groups on the lower side of the leaf (Fig. 328). These orange or yellow æcidia are termed cluster-cups. In Fig. 329 is shown a cross-section of one of the cups, outlining the long chains of spores, and the mycelium in the tissues.


328. Leaf of barberry with cluster-cups.

The æcidiospores are formed in the spring, and after they have been set free some of them lodge on wheat or other grasses, where they germinate immediately. The germ-tube enters the leaf through a stomate, whence it spreads among the cells of the wheat plant. During summer one-celled *uredospores* ("blight spores") are produced in a manner similar to the teleutospores. These are capable of germinating immediately and serve to disseminate the fungus during the summer on other wheat plants or grasses (Fig. 330). Late in the season, teleutospores are again produced, completing the life cycle of the plant.

Many rusts beside Puccinia graminis produce different spore-forms on different plants. The phenomenon is called *heterœcism*, and was first shown to exist in the wheat rust. Curiously enough, the peasants of Europe had observed and asserted that barberry bushes cause wheat to blight long before science explained the relation between the cluster-cups on barberry and the rust on wheat. The true relation was actually demonstrated, as has since been done for many other rusts on their respective hosts by sowing the cæidiospores on healthy wheat plants and thus producing the rust. The cedar apple is another rust, producing the curious swellings often found on the branches of red cedar trees. In the spring the teleutospores ooze out from the "apple" in brownish yellow masses. It has been found that these attack various fruit trees producing æcidia on their leaves.


329. Section through a cluster-cup on barberry leaf.


330. Uredospores of wheat rust.

LICHENS

Lichens are so common everywhere that the attention of the student is sure to be drawn to them. They grow on rocks (Fig. 346), trunks of trees, old fences, and on the earth. They are too difficult for beginners, but a few words of explanation may be useful.

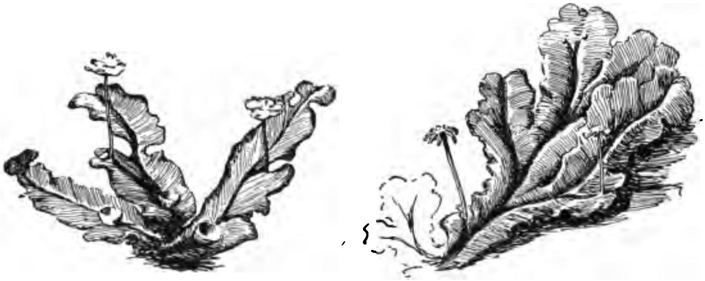
Lichens were formerly supposed to be a distinct or separate tribe of plants, and many species have been described. They are now known to be the green cells of various species of algæ, overgrown and held together (imprisoned) by the mycelium of various kinds of fungi. The result is a growth unlike either component. This association of alga and fungus is usually spoken of as *symbiosis*, or mutually helpful growth, the alga furnishing some things, the fungus others, and both together being able to accomplish work which neither could do independently. By others this union is considered to be a mild form of parasitism, in which the fungus profits at the expense of the alga. As favorable to this view, the facts are cited that each component is able to grow independently, and that under such conditions the algal cells seem to thrive better than when imprisoned by the fungus.

Lichens propagate by means of *soredia*, which are tiny parts separated from the body of the thallus, and consisting of one or more algal cells overgrown with fungous threads. These are readily observed in many lichens. They also produce spores, usually ascospores, which are always the product of the fungous element, and which reproduce the lichen by germinating in the presence of algal cells, to which the hyphæ immediately cling.

Lichens are found in the most inhospitable places and, by means of acids which they secrete, they attack and slowly disintegrate even the hardest rocks. By making thin sections of the thallus with a sharp razor and examining under the compound microscope, it is easy to distinguish the two components in many lichens.

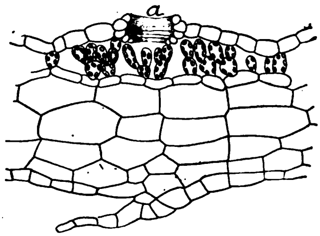
LIVERWORTS

The liverworts are peculiar, flat, green plants usually found growing on wet cliffs and in other moist, shady places. They frequently occur in greenhouses where the soil is kept constantly wet. One of the commonest liverworts is Marchantia polymorpha, two plants of which are shown in Figs. 331, 332. The plant consists of a flat ribbonlike thallus which creeps along the soil, becoming repeatedly forked as it grows. The end of each branch is always conspicuously notched. There is a prominent midrib extending along the center of each branch of the thallus. On the under side of the thallus, especially along the midrib, there are numerous rhizoids which serve the purpose of roots, absorbing nourishment from the earth and holding the plant in its place. The upper surface of the thallus is divided into minute rhombic areas which can be seen with the naked eye. Each of these areas is perforated by a small breathing pore or stomate which leads into a cavity just beneath the epidermis. This space is surrounded by chlorophyll-bearing cells, some of which stand in rows from the bottom of the cavity (Fig. 333). The delicate assimilating tissue is thus brought in close communication with the outer air through the pore in the thick protecting epidermis.


331. 332.
Plants of marchantia.

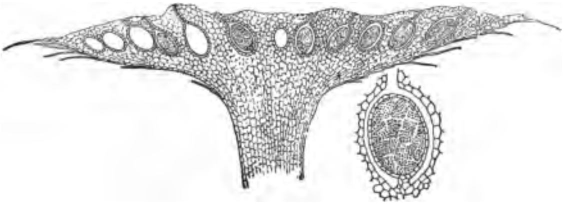
At various points on the midrib are little cups which contain small green bodies. These bodies are buds or *gemmæ* which are outgrowths from the cells at the bottom of the cup. They become loosened and are then dispersed by the rain to other places where they take root and grow into new plants.

The most striking organs on the thallus of marchantia are the peculiar stalked bodies shown in Figs. 331, 332. These are termed *archegoniophores* and *antheridiophores* or *receptacles*. Their structure and function are very interesting, but their parts are so minute that they can be studied only with the aid of a microscope magnifying from 100 to 400 times. Enlarged drawings will guide the pupil.



333. Section of thallus of marchantia. Stomate at *a*.

The antheridiophores are fleshy lobed disks borne on short stalks (Fig. 331). The upper surface of the disk shows openings scarcely visible to the naked eye. However, a section of the disk, such as is drawn in Fig. 334, shows that the pores lead into oblong cavities in the receptacle. From the base of each cavity there arises a thick club-shaped body, the antheridium. Within the antheridium are formed many sperm-cells which are capable of swimming about in water by means of long lashes or cilia attached to them. When the antheridium is mature, it bursts and allows the ciliated sperm-cells to escape.

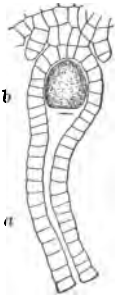


334. Section through antheridiophore of marchantia, showing antheridia. One antheridium more magnified.

The archegoniophores are also elevated on stalks (Fig. 332). Instead of a simple disk, the receptacle consists of nine or more finger-like rays. Along the under side of the rays, between delicately fringed curtains, peculiar flask-like bodies, or archegonia, are situated. The archegonia are not visible to the naked eye. They can be studied only with the microscope (× about 400). One of them much magnified is represented in Fig. 335. Its principal parts are the long *neck*, *a*, and the rounded *venter*, *b*, inclosing a large free cell—the egg-cell.

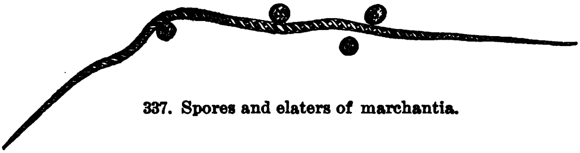
We have seen that the antheridium at maturity discharges its sperm-cells. These swim about in the water provided by the dew and rain. Some of them finally find their way to the archegonia and egg-cells, which are thus fertilized, as pollen fertilizes the ovules of higher plants.

After fertilization the egg-cell develops into the spore-capsule or *sporogonium*. The mature spore-capsules may be seen in Fig. 336. They consist of an oval spore-case on a short stalk, the base of which is imbedded in the tissue of the receptacle from which it derives the necessary nourishment for the development of the sporogonium. At maturity the sporogonium is ruptured at the apex,



335. Archegonium of marchantia.

336. Archegoniophore with sporogonia of marchantia.

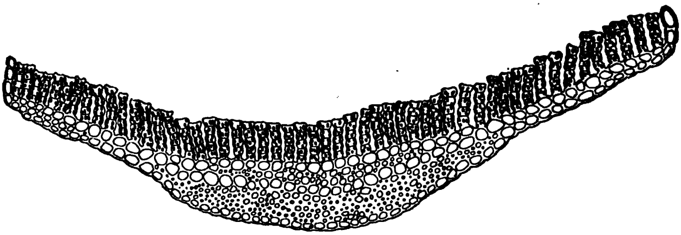


337. Spores and elaters of marchantia.

setting free the spherical spores together with numerous filaments having spirally thickened walls (Fig. 337). These filaments are called *elaters*. When drying, they exhibit rapid movements by means of which the spores are scattered. The spores germinate and again produce the thallus of marchantia.

MOSSES

If we have followed carefully the development of marchantia, the study of one of the mosses will be comparatively easy. The mosses are more familiar plants than the liverworts. They grow on trees, stones, and on the soil both in wet and dry places. One of the common larger mosses, known as Polytrichum commune, may serve as an example. This plant grows on rather dry knolls, mostly in the borders of open woods, where it forms large beds. In dry weather these beds have a reddish brown appearance, but when moist they form beautiful green cushions. This color is due, in the first instance, to the color of the old stems and leaves and, in the second instance, to the peculiar action of the green living leaves under the influence of changing moisture-conditions. The inner surface of the leaf is covered with thin, longitudinal ridges of delicate cells which contain chlorophyll. These are shown in cross-section in Fig. 338. All the other tissue of the leaf consists of thick-walled, corky cells which do not allow moisture to penetrate. When the air is moist the green leaves spread out, exposing the chlorophyll cells to the air, but in dry weather the mar-



338. Section of leaf of Polytrichum commune.

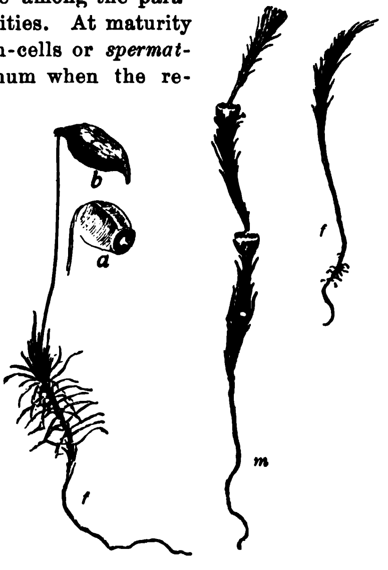
gins of the leaves roll inward, and the leaves fold closely against the stem, thus protecting the delicate assimilating tissue.

The antheridia and archegonia of polytrichum are borne in groups at the ends of the branches on different plants (many mosses bear both organs on the same branch). They are surrounded by involucres of characteristic leaves termed *perichætia* or *perichætal leaves.* Multicellular hairs known as *paraphyses* are scattered among the archegonia and antheridia. The involucres with the organs borne within them are called *receptacles* or, less appropriately, "moss flowers." As in marchantia, the organs are very minute and must be highly magnified to be studied.

339. Section through a receptacle of Polytrichum commune, showing paraphyses and antheridia.

The antheridia are borne in broad cup-like receptacles on the antheridial plants (Fig. 339). They are much like the antheridia of marchantia, but they stand free among the paraphyses and are not sunk in cavities. At maturity they burst and allow the sperm-cells or *spermatozoids* to escape. In polytrichum when the receptacles have fulfilled their function the stem continues to grow from the center of the cup (Fig. 340, *m*). The archegonia are borne in other receptacles on different plants. They are like the archegonia of marchantia except that they stand erect on the end of the branch.

The sporogonium which develops from the fertilized egg is shown in Fig. 340, *a*, *b*. It consists of a long, brown stalk bearing the spore-case at its summit. The base of the stalk is embedded in the end of the moss stem by which it is nourished. The capsule is entirely inclosed by a hairy cap, the *calyptra*, *b*. The calyptra is really the remnant of the archegonium, which, for a time, increases in size to accommodate



340. Polytrichum commune; *f*, *f*. fertile plants, one on the left in fruit; *m*, antheridial plant.

and protect the young growing capsule. It is finally torn loose and carried up on the spore-case. The mouth of the capsule is closed by a circular lid, the *operculum*, having a conical projection at the center. The operculum soon drops, or it may be removed, displaying a fringe of sixty-four teeth guarding the mouth of the capsule.

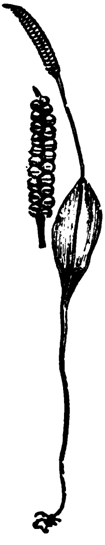
This ring of teeth is known as the *peristome*. In most mosses the teeth exhibit peculiar hygroscopic movements, i. e., when moist they bend outwards and upon drying curve in toward the mouth of the capsule. This motion, it will be seen, serves to disperse the spores gradually over a long period of time.

Not the entire capsule is filled with spores. There are no elaters, but the center of the capsule is occupied by a columnar strand of tissue, the columella, which expands at the mouth into a thin, membranous disk, closing the entire mouth of the capsule except the narrow annular chink guarded by the teeth. In this moss the points of the teeth are attached to the margin of the membrane, allowing the spores to sift out through the spaces between them.

When the spores germinate they form a green, branched thread, the *protonema*. This gives rise directly to moss plants, which appear as little buds on the thread. When the moss plants have sent their little rhizoids into the earth, the protonema dies, for it is no longer necessary for the support of the little plants.

FERNS

The adder's tongue fern, Ophioglossum vulgatum, shown in Fig. 341, is one of a peculiar type of ferns belonging to the family Ophioglossaceæ. This plant has a short, subterranean stem from which a single frond unfolds each year. The roots arise near the bases of the leaves. The leaves are curiously divided into a sterile and a fertile part, the latter being a sporophyll. The sterile part has a tongue-shaped blade which is narrowed to a petiole. The young leaves are inclosed by the sheathing base of the petiole. The growth is very slow, so that it takes several years for each leaf to develop before it is ready to unfold. During its development each leaf is sheathed by the one preceding it.



341. Ophioglossum vulgatum.

The sporophyll is elevated on a stalk arising near the base of the sterile part of the frond. The upper part consists of a spike bearing two rows of large spore-cases or sporangia sunk in the tissue. At maturity the sporangia open by transverse slits and discharge the inclosed spores.

When the spores germinate they produce subterranean tuberous prothallia which, however, are rarely found, and of whose history little is known. They develop archegonia and antheridia beneath the surface of the ground, and the fertilized egg produces the young fern plant.

The generations of the true ferns are explained in Chapter XXIV.

EQUISETUMS, OR HORSETAILS

There are about twenty-five species of equisetum, constituting the only genus of the unique family Equisetaceæ. Among these E. arvense is common on clayey and sandy soils.

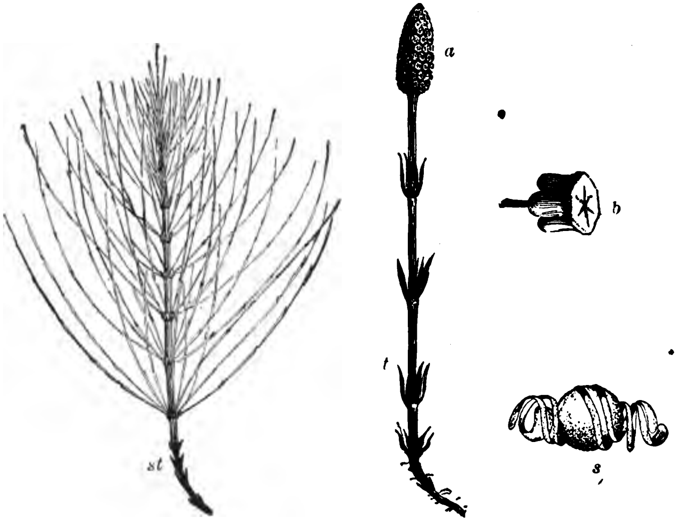
In this species the work of nutrition and that of spore-production are performed by separate shoots from an underground rhizome. The fertile branches appear early in spring. The stem, which is 3 to 6 inches high, consists of a number of cylindrical, furrowed internodes each sheathed at the base by a circle of scale-leaves. The shoots are of a pale yellow color. They contain no chlorophyll, and are nourished by the food stored in the rhizome (Fig. 342).

The spores are formed on specially developed fertile leaves or sporophylls which are collected into a spike or cone at the end of the stalk (Fig. 342, *a*). A single sporophyll is shown at *b*. It consists of a short stalk expanded into a broad, mushroom-like head. Several large sporangia are borne on its under side.

The spores formed in the sporangia are very interesting and beautiful objects when examined under the microscope (× about 200). They are spherical, green bodies each surrounded by two spiral bands attached to the spore at their intersection, *s*. These bands exhibit hygroscopic movements by means of which the spores become entangled, and are held together. This is of advantage to the plant, as we shall see.

All the spores are alike, but some of the prothallia are better nourished and grow to a greater size than the others. The large prothallia produce only archegonia while the smaller ones produce antheridia. Both of these organs are much like those of the ferns, and fertilization is accomplished in the same way. Since the prothallia are usually diœcious the special advantage of the spiral bands holding the spores together so that both kinds of prothallia may be in close proximity, will be easily understood. As in the fern, the fertilized egg-cell develops into an equisetum plant.

The sterile shoots, Fig. 342, *st*, appear much later in the season. They give rise to repeated whorls of angular or furrowed branches. The leaves are very much reduced scales, situated at the internodes. The stems are provided with chlorophyll and act as assimilating tissue, nourishing the rhizome and the fertile shoots. Nutriment is also stored in special tubers developed on the rhizome.



342. Equisetum arvense; *st*, sterile shoot; *f*, fertile shoot showing the spike at *a*; *b*, sporophyll, with sporangia; *s*, spore.

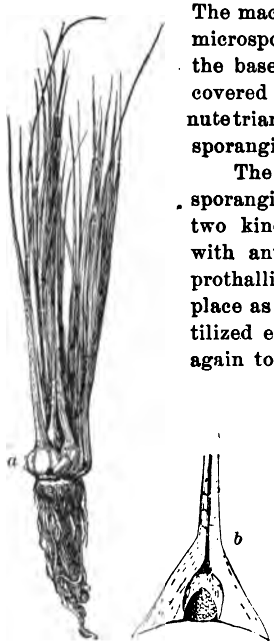
Other species of equisetum have only one kind of shoot—a tall, hard, leafless, green shoot with the spike at its summit. Equisetum stems are full of silex and they are sometimes used for scouring floors and utensils: hence the common name "scouring rush."

ISOËTES

Isoëtes or quillworts are usually found in water or damp soil on the edges of ponds and lakes. The general habit of a plant is seen in Fig. 343, *a*. It consists of a short, perennial stem bearing numerous erect, quill-like leaves with broad sheathing bases. The plants are commonly mistaken for young grasses.

Isoëtes bears two kinds of spores, large roughened ones, the *macrospores*, and small ones or *microspores*. Both kinds are formed in sporangia borne in an excavation in the expanded base of the leaf. The macrospores are formed on the outer, and the microspores on the inner leaves. A sporangium in the base of a leaf is shown at *b*. It is partially covered by a thin membrane, the *velum*. The minute triangular appendage at the upper end of the sporangium is called the *ligule*.

The spores are liberated by the decay of the sporangia. They form rudimentary prothallia of two kinds. The microspores produce prothallia with antheridia, while the macrospores produce prothallia with archegonia. Fertilization takes place as in the mosses or liverworts, and the fertilized egg-cell, by continued growth, gives rise again to the isoëtes plant.



343. Isoëtes showing habit of plant at *a*; *b*, base of leaf showing sporangium, velum, and ligule.

ALTERNATION OF GENERATIONS

In Chapter XXIV the *alternation of generations* and the terms *gametophyte* and *sporophyte* were explained. In many of the plants just studied, this alternation is more clearly and beautifully marked than in any other groups of plants. In each generation, the reproductive body (egg or spore) gives rise to a new plant-form or generation different from the parent generation. In the liverworts the thallus produces the egg. The fertilized egg-cell is the beginning of a new plant, but this new plant is not like the thallus which produced the egg, nor does it lead an independent existence. It is the sporogonium, which, although it is attached to the thallus, is not a morphological part thereof. The sporogonium produces spores. It is the sporophyte generation of the plant, and not until the spores germinate is the thallus again produced. The same is true in the mosses. The "moss plant" produces the egg-cells. It is the gametophyte. The fertilized egg-cell develops into the sporophyte—the spore-case and its stem. We can pull the stem of the capsule out of the moss plant and thus separate the sporophyte from the gametophyte.

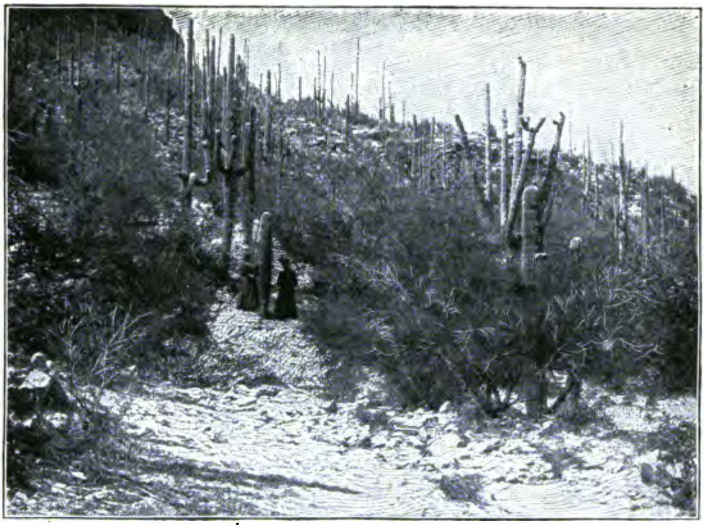
The fungi and algæ are omitted from these remarks. In the former there is nothing analogous to the sporophyte and the gametophyte. In algæ like spirogyra, evidently the whole plant is a gametophyte and, since the zygospore germinates directly into a new gametophyte, there is probably no sporophyte. In some other algæ traces of a sporophyte have been found, but the discussion of these would lead too far for the present purpose.

In the ferns the egg-cells are developed on the prothallus. This then is the gametophyte. It corresponds to the thallus of marchantia and to the "moss plant," but it has become much reduced. The plant developing from the fertilized egg-cell is the large and beautiful "fern plant" differentiated into stems and leaves. Since the fern plant produces the spores directly, it is the sporophyte and corresponds to the shaft and capsule of the mosses. Both sporophyte and gametophyte lead an independent existence.

As we pass on to equisetum and isoëtes, the sporophyte is still more conspicuous in comparison with the gametophyte. In isoëtes the prothallus (gametophyte) is very rudimentary, consisting only of a few cells remaining within the spore, which merely bursts to expose the archegonia or to allow the sperm-cells to escape. Moreover, the spores have become differentiated into micro- and macrospores corresponding to the pollen and embryo-sac of higher plants.

This gradual increase of the sporophyte and reduction of the gametophyte can be traced on through the flowering plants in which "the plant" is the sporophyte, and the gametophyte is represented simply by a few cells in the germinating pollen grain, and in the embryo-sac.

One of the tuft-mosses (Leucobryum).
Outside and inside views of a tuft, the latter showing the radiating stems extending to the light.



344. Desert vegetation.
The tree cacti grow only in special regions. Arizona.

345. Plants seize the first opportunity to grow. Palisades of the Hudson.

PART II—THE PLANT IN ITS ENVIRONMENT

CHAPTER XXVI

WHERE PLANTS GROW

326. **ENVIRONMENT.**—The circumstances and surroundings in which an organism lives constitute its **environment.** The environment comprises effects of *soil*, *moisture*, *temperature*, *altitude*, *sunlight*, *competition with animals and other plants*, and the like. An organism is greatly influenced by the environment or conditions in which it lives. Not only must a plant live and grow and multiply its kind, but it must **adapt itself to its environment.**

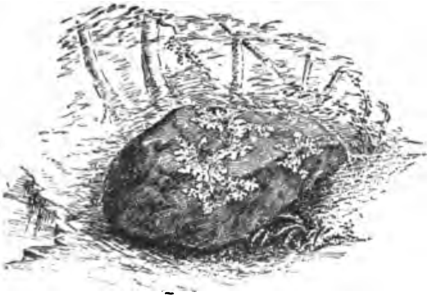
327. The particular place in which a plant grows is known as its **habitat** (i. e., its "habitation"). The habitat of a given plant may be a swamp, hill, rock, sand plain, forest, shore. The plant inhabitants of any region are known collectively as its **flora.** Thus we speak of the flora of a meadow or a hill or a swamp, or of a country. The word is also used for a book describing the plants of a region (as in Part IV).

328. **PLANTS GROW WHERE THEY MUST.**—The plant is not able to choose its environment. It has no volition. Its seeds are scattered: only a few of them fall in pleasant places. The seeds make an effort to grow even though the places are not favorable; and so it happens

that *plants are often found in places which are little adapted to them.* See the fern growing on a brick in Fig. 69. Plants must grow in **unoccupied places.**

329. Not only do the seeds fall in unfavorable places, but most places are already occupied. So it comes that **plants grow where they must, not where they will.** There are, of course, certain limits beyond which plants cannot grow. Water lilies can thrive only in water, and white oaks only on dry land, but it is seldom that either the water lily or the oak finds the most congenial place in which to grow. Fine large plants of the lily and strong giant trees of the oak are so infrequent, as compared with the whole number, that we stop to admire them.

330. Originally, plants were **aquatic,** as animals were. Much of the earth was sea. Many plants are now aquatic, and the larger number of these—as algæ and their kin—belong to the lower or older forms of plant life. Many plants of higher organization, however, as the water lilies, have taken to aquatic life. True aquatic plants are those *which always live in water, and which die when the water dries up.* They are to be distinguished from those which live on shores or in swamps. Aquatic plants may be wholly *immersed* or under water, or partly *emersed* or standing above the water. Most flowering aquatic plants come to the surface to expand their flowers or to ripen their fruits. Some aquatic plants are *free-swimming,* or not attached to the bottom. Of this kind are some utric-



316. The lichen grows on the hard rock.

ularias, or bladder-worts. In some waters, particularly in the ocean, there are enormous quantities of free-swimming microscopic life, both animal and vegetable, which is carried about by currents: this is known under the general name of *plankton* (Greek for "wandering" or "roaming").

331. The general tendency has been for plants to become **terrestrial**, or land-inhabiting. Terrestrial plants often grow in wet places, but never in water throughout their entire life; of such are *swamp*, *bog*, and *marsh plants*. Some plants have the ability to grow in standing water when young and to become terrestrial as the water dries up. Such are **amphibious.** Some buttercups are examples.

317. Sphagnum bog, green and living on top, but dead and dying underneath. Sphagnum moss is used by nurserymen and florists as packing material for plants.

332. Some plants grow in very **special soils** or **special localities**, and consequently are infrequent or are confined to certain well-marked geographical regions. Fig. 344. *Common plants are those which are able to accommodate*

themselves to widely different environments. Weeds are examples. Many plants have become so specialized in habitat as to be parasitic, saprophytic, or epiphytic. Chap. XIII.

333. **Common plants often grow in most unusual and difficult places.** Note that some weeds grow not only in fields, but often gain a foothold in chinks in logs, on rotting posts, in crotches of trees, on old straw stacks, in clefts and crannies of rocks. In moist climates, as England, plants often grow on thatched roofs.

334. Plants may be said to be seeking **new places in which to grow.** Whenever ground is cleared of vegetation, plants again spring up. The farmer plows the meadow or pasture, and immediately a horde of weeds appears. Any breach or break in the earth's surface makes room for a new group of plants. Note how the railway embankments and the newly graded roadsides take on a covering of vegetation. Observe the ragweed. Whenever soil is formed at the base of a cliff, plants at once secure a foothold. Fig. 345.

335. **PLANTS AID IN THE FORMATION OF SOIL.** — This they do in two ways: **by breaking down the rock; by passing into earth when they decay.** Even on the hardest rocks, lichens and mosses will grow. Fig. 346. The rhizoids eat away the rock. A little soil is formed. Ferns and other plants gain a foothold. The crevices are entered and widened. Slowly the root acids corrode the stone. Leaves and stems collect on the rock and decay. Water and frost lend their aid. As the centuries pass, the rock is eaten away and pulverized. Note the soil which collects on level rocks in woods where wind and rain do not remove the accumulations.

336. In bogs and marshes and on prairies the remains of plants form a deep black soil. In bogs the vegetable matter is partially preserved by the water, and it slowly becomes solidified into a partially decayed mass known as

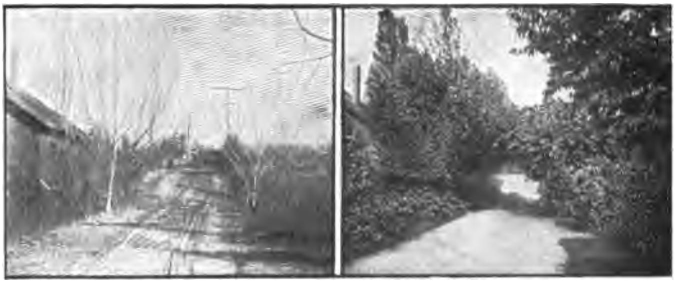
348. A landscape devoid of vegetation. Western United States.

349. A landscape with vegetation. Holland.

peat. When dug out and dried, peat may be used as fuel. Finally it may decay and make a vegetable soil known as **muck.** When thoroughly decayed, plants become **vegetable mold** or **humus.** New plants grow on peat or muck, and the accumulations year by year tend to raise the level of the bog, and the surface may finally become so high as to support plants of the high lands. The chief agent in the formation of peat bogs is sphagnum moss. New moss grows on the old, and the bog becomes higher as time goes on. Fig. 347.

337. **PLANTS CONTRIBUTE TO SCENERY.** — Aside from sky and air, natural scenery depends chiefly on two things: the physical contour of the earth; the character of the vegetation. Attractive landscapes have a varied vegetation. Imagine any landscape with which you are familiar to be devoid of plants. Compare Figs. 348 and 349.

REVIEW.— What is meant by environment? By habitat? Flora? What determines where plants shall grow? What is an aquatic plant? Explain immersed, emersed, free-swimming. What is plankton? Explain terrestrial. Amphibious. Why are some plants rare or local? Why are some plants common? Name some unusual places in which you have seen plants growing. Give examples of how plants occupy the new places. How do plants aid in the formation of soil? Explain what is meant by peat, muck, humus. How are peat bogs formed? What relation have plants to scenery?



The same landscape in winter and summer.

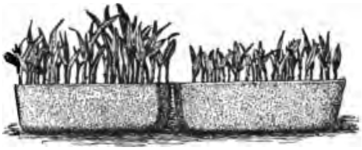
CHAPTER XXVII

CONTENTION WITH PHYSICAL ENVIRONMENT

338. **THE PHYSICAL ENVIRONMENT.** — We have seen (326) that the environment in which a plant grows is made up of two sets of factors — the **physical environment** of climate and soil, and the *organic environment* of competing animals and plants.

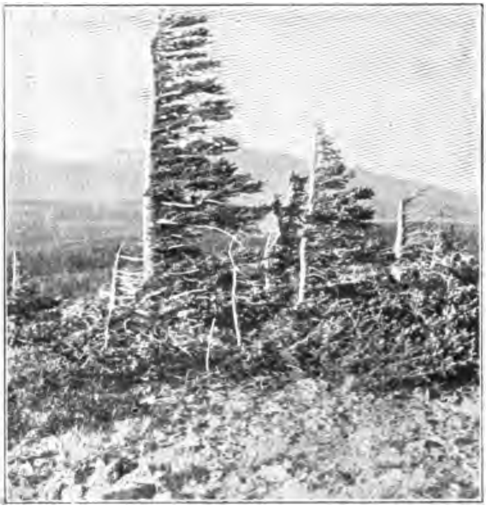
339. **ADAPTATION TO CLIMATE IN GENERAL.** — Every particular climate causes particular modifications in its plants. There are two general ways, however, in which plants are modified or adapted to climate: modification in the *length of the period of growth;* modification in *stature.* Any modification of the plant, visible or invisible, which adapts it to grow in a climate at first injurious to it, is **acclimatization.**

340. *In short-season climates, plants hasten their growth.* They **mature quickly.** Indian corn may require five or six months in which to mature in warm countries, but only three months in very cold countries. Nearly all garden vegetables mature quicker from the time of planting in the North than in the South when they are raised **from** seeds grown in their respective localities. Seedsmen are aware of this and they like to raise seeds of early varieties in the North, for such seeds usually give "early" plants. Many plants which are perennials in warm countries become annuals or plur-annuals in cold countries(14).



350. Germination of corn grown in New York (on the left) and in Alabama.

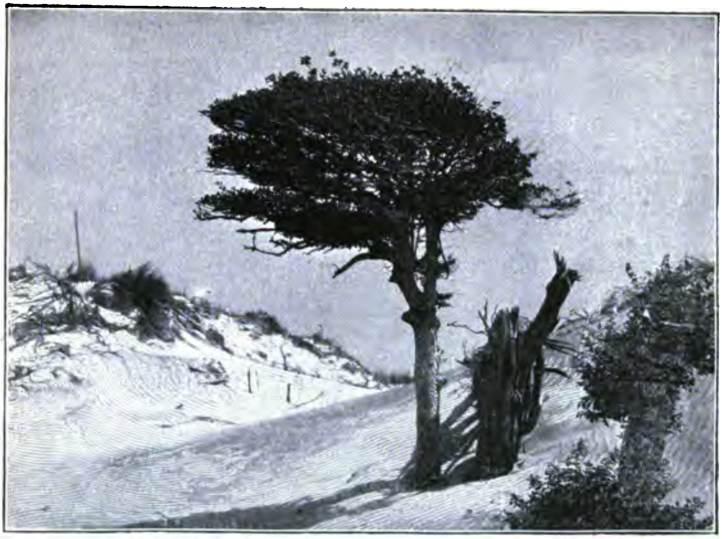
341. Even **germination is usually more rapid from northern-grown seeds** than from southern-grown seeds of the same kind. The plants "come up" quicker. Secure seeds of the same variety of corn or bean grown in the Gulf states and in the northern states or Canada and make the experiment (Fig. 350). The same results often show in the vegetation of cuttings of trees and grape vines from the South and North. Vegetation is quick in the North: the "burst of spring" is usually more rapid.



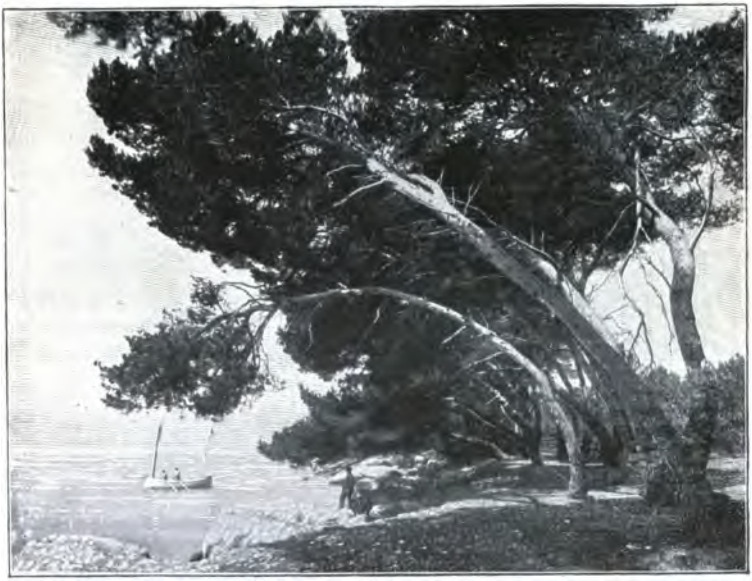
351. Evergreen trees on wind-swept heights of the Rocky Mountains.

342. Plants are usually **dwarf** or **smaller in stature** in short-season climates. Indian corn is a conspicuous example. As one ascends high mountains or travels in high latitudes, he finds the trees becoming smaller and smaller, until finally he passes beyond the regions in which the trees can grow. Many of the Esquimaux doubt the statements of travelers that there are plants as high as a man. In these high altitudes and high latitudes, plants tend also to become *prostrate*.

343. **PLANTS ARE INFLUENCED BY WIND.**—In regions of strong prevailing winds, as on lake and sea shores and on hills and mountains, tree-tops develop unsymmetrically

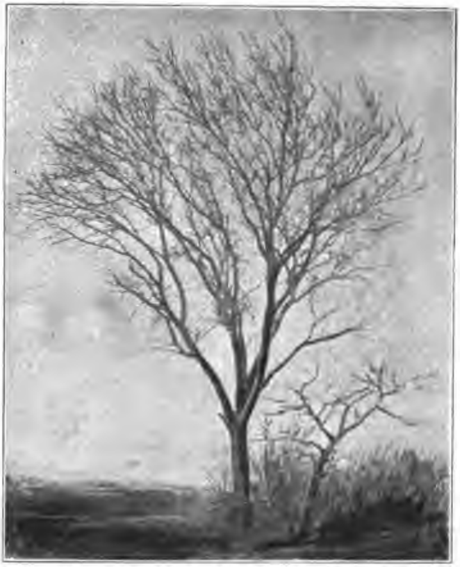


352. One-sided holly tree growing near the ocean. New Jersey.



353. Pines probably bent by winds falling from mountains.

and are **heaviest on the leeward side.** Figs. 351, 352. Observe this fact in orchards in windy regions, and note that the most unsymmetrical trees are those on the exposed side of the plantation.



354. A tree that shows which way the wind blows. Oklahoma.

344. Trees often **lean away from the prevailing winds.** Fig. 353. The **tips of the branches** of exposed trees usually indicate whether there are strong prevailing winds. Fig. 354. Observe trees in pastures and along roadsides, particularly in high places and within a few miles of exposed shores. Note the tip-top spray of hemlock trees.

345. **PLANTS ARE PROFOUNDLY INFLUENCED BY SOIL.**—The food supply varies with the kind of soil; and the **food supply determines to a large extent the character of the individual plant.** On poor soils plants are small; on rich soils they are large. The difference between poor and good yields of wheat, or any other crop, is largely a question of soil. The farmer reinforces his poor soils by the addition of fertilizers, in order to make his plants vary into larger or more productive individuals.

346. **The moisture-content of the soil exerts a marked influence on plants.** We have found (154) that a large

part of the plant-substance is water. The water is not only itself plant-food, but it carries other foods into the plant and transports them from tissue to tissue. However rich a soil may be in mineral plant-foods, it is inert if it contains no moisture. *The character of the plant is often determined more by the moisture in the soil than by all the other food materials.* Note how rank the plants are in low places. Observe how the weeds grow about the barn where the soil is not only rich but where moisture is distributed from the eaves. Contrast with these instances the puny plants which grow in dry places. In dry countries irrigation is employed to make plants grow vigorously. In moist and rich soil plants may grow so fast and so tall as not to be able to withstand the wind, as in Fig. 355.

355. "Lodged" oats. On rich ground the grain is often broken by wind and rain, the plants having grown so heavy as to be unable to support themselves.

347. **PLANTS ARE INFLUENCED BY THE EXPOSURE OF THE PLACE IN WHICH THEY GROW.**—The particular site or outlook is known as the *exposure* or *aspect*. The exposure, for instance, may be southward, eastward, bleak, warm,

cold. A favorable exposure for any plant is one which supplies the requisite amount of warmth, room, sunlight, moisture, and plant-food, and immunity from severe winds and other destructive agencies. Against the edge of a forest (Fig. 356) or at the base of a cliff, certain plants thrive unusually well. Note the plants of any kind growing in different exposures: observe that they vary in stature, time of maturity, color of foliage and flowers, productiveness, size of leaves and flowers, longevity.

356. The flowering dogwood is seen at its best along the margins of the wood.

REVIEW.—Contrast physical and organic environments. How are plants modified by climate? Define acclimatization. Explain how time of maturity is influenced by climate. How is germination influenced? Explain how climate influences stature. How do winds affect plants? How are plants influenced by soil? By soil moisture? Exposure?

CHAPTER XXVIII

COMPETITION WITH FELLOWS

348. **THE FACT OF STRUGGLE FOR EXISTENCE.**—We have seen (Chapter IX) that branches contend amongst themselves for opportunity to live and grow. Similarly, separate **plants contend with each other.** We shall observe that this is true; but we are compelled to believe it by considering the efforts which all plants make to propagate themselves. *The earth is filled with plants.* It is chiefly when plants die or are killed that places are made for others. Every one of these plants puts forth its utmost effort to perpetuate its kind. It produces seeds by the score or even by the thousand. In some instances it propagates also by means of vegetative parts. If the earth is full and if every plant endeavors to multiply its kind, there must be struggle for existence.

349. The effects of struggle for existence are of three general categories: (1) **the seed or spore may find no opportunity to grow**; (2) **sooner or later the plant may be killed**; (3) **the plant may vary,** or take on new characters, to adapt itself to the conditions in which it grows. Consider the crop of seeds which any plant produces: how many germinate? how many of the young plants reach maturity? Note the profusion of seedlings under the maples and elms, and then consider how few maple and elm trees there are. Count the seeds on any plant and imagine that each one makes a plant: where will all these new plants find a place in which to grow?

350. **WHAT STRUGGLE FOR EXISTENCE IS.**—Struggle for existence with fellows is competition for **room** or

357. There is no opportunity for weeds in a field of good wheat.

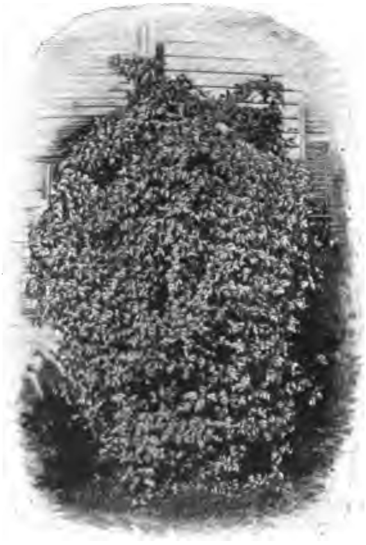
358. Divergence of character in a cornfield.

359. The tree has appropriated the food and moisture, so that a large area remains bare of vegetation.

space, for food and moisture in the soil, for light. We may consider examples in each of these three categories.

351. If the earth is filled with plants, **there must be sharp competition for every inch of its surface.** If any good soil is not populated with plants it is usually because it has recently been moved. If the farmer does not move or till his soil frequently, various plants get a foothold, and these plants he calls weeds. Determine how much room an apple tree, or other plant, occupies: then calculate how much space would be required for all the seedlings of that tree or plant. *The greater the population of any area, the less chance have other plants to gain a foothold.* When the wheat completely covers the ground, as in Fig. 357, there are no weeds to be seen.

352. *Plants of different form and habit may grow*



360. The clematis climbing into the sunlight. Compare Fig. 73.

361. Low shade-loving plants on the forest floor.

362. A primeval pine forest.
Along the roadway foreign vegetation has come in. Michigan.

together, and thereby the area may support more plants than would be possible if only one kind were growing on it. This principle has been called by Darwin the **divergence of character.** When an area is occupied by one kind of plant, another kind may grow between or beneath. Only rarely do plants of close botanical relationship grow together in compact communities. A field which is full of corn may grow pumpkins between. Fig. 358. A full meadow may grow white clover in the bottom. In a dense wood herbs may grow on the forest floor. When an

363. On the top of an evergreen forest.

364. The tell-tale pine.

orchard can support no more trees, weeds may grow beneath.

353. We have learned (25, 26) that *roots go far and wide for food and moisture.* **The plant that is first established appropriates the food to itself and newcomers find difficulty in gaining a foothold.** Note the bare area near the elm tree in Fig. 359. Recall how difficult it is to make plants grow when planted under trees. This is partly due to the intercepting of the rain by the tree-top, partly to shade, and partly to lack of available food and moisture in the soil. The farmer knows that he cannot hope to secure good crops near large trees, even beyond the point at which the trees intercept the rain and light. It is difficult to establish new trees in the vacancies in an old orchard.

354. In Chapter VIII we studied the relation of the plant and its parts to sunlight. Plants also **compete with each other for light.** Plants climb to get to the light (Chapter XVI). Fig. 360. Some plants have become adapted to

365. The forest center. Looking from the woods, with the forest rim shown in Fig. 366 seen in the distance.

subdued or transmitted light, but no green plants can grow in darkness. The low plants in forests are shade-lovers. Fig. 361. Note the plants which seem to be shade-lovers and those which prefer full sunlight. Some plants adapt themselves to both sun and shade. Most ferns are shade-lovers.

355. In the midst of dense plant populations, each individual **grows upwards for sunlight.** Thus are forests made: the competing trees become long slender boles with a mantle of foliage at the top. The side branches die for lack of light and food, and they fall from decay or are broken by storm; the wounds are healed, and the bole becomes symmetrical and trim. Fig. 362 shows the interior of a primeval pine forest. Note the bare trunks and the sparse vegetation on the dim forest floor. Fig. 363 is the top of a great forest. With these pictures compare Figs. 75 and 76. Fig. 357 shows a deep wheat forest. **A lone survivor of a primeval forest is shown in Fig. 364.**

366. The forest rim. Looking towards the woods.

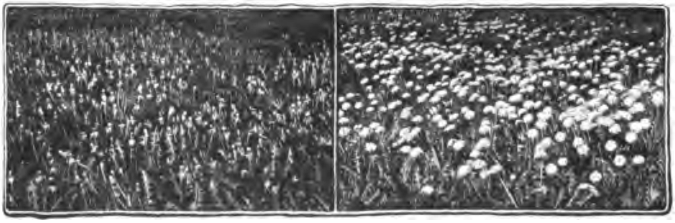
367. The foliage bank of a tangle.

368. View just inside the tangle.

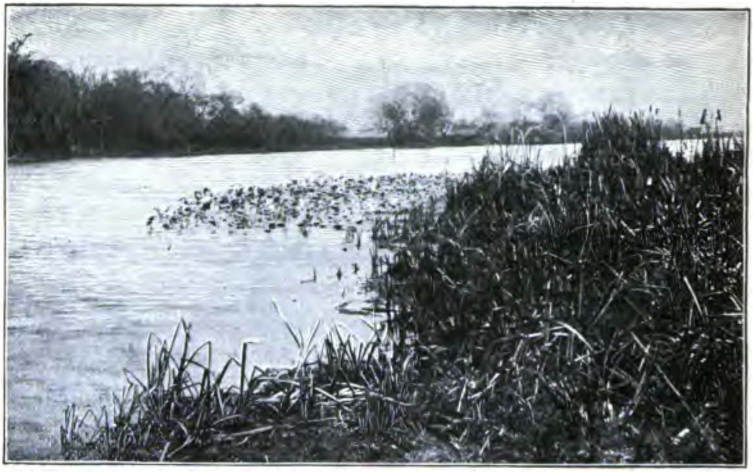
In dense plantations, plants tend to grow to a *single stem*. When these same plants are grown in open or cultivated grounds, *they often become bushy or develop more than one trunk*. In what places have you seen trees with more than one trunk?

356. On the margins of dense populations, each individual **grows outwards for sunlight.** Note the dense forest rim: then plunge through it, and stand by the tall bare trunks. Figs. 365 and 366 show these two views of the same forest. Note the kinds of trees and other plants that grow in areas similar to those depicted in these illustrations. Note the dense wall of foliage in Fig. 367, and the thin brushy area just behind it in Fig. 368. Observe the denser and greener foliage on the outside rows in thick orchards. Consider how the plants extend over the borders in dense flower-beds. Note where the best foliaged plants are in the greenhouse. Notice the foliage on the outer rows in a very thick cornfield.

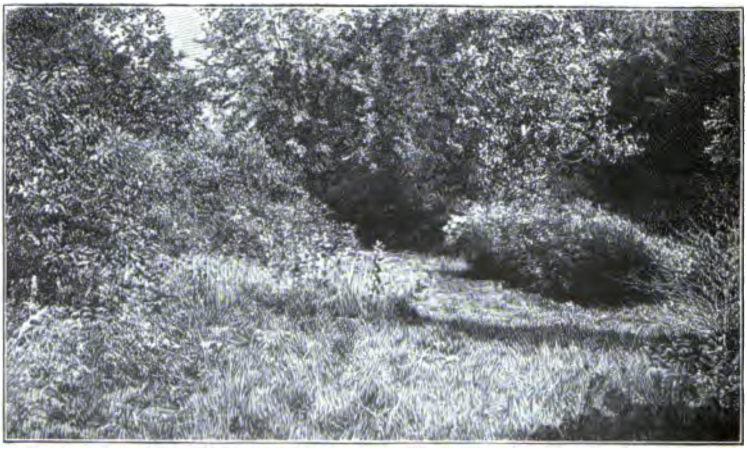
REVIEW.—Why is there struggle for existence? How does it affect plants? Tell what it is. How do plants compete for space? What is meant by the phrase "divergence of character"? Give examples. How do plants compete for food from the soil? In what respects have plants become adapted to the light relation? How do plants grow in dense plantations? On the margins of these plantations? You know some tree or other plant: describe how it has adapted itself to competition with its fellows.



A dandelion knoll in shade and sun.



369. A hydrophytic society. New York.



370. A mesophytic society. Michigan.

CHAPTER XXIX

PLANT SOCIETIES

357. **WHAT PLANT SOCIETIES ARE.**—In the long course of evolution, in which plants have been accommodating themselves to the varying conditions in which they are obliged to grow, *plants have become adapted to every different environment*. Certain plants, therefore, may live together or near each other, all enjoying the same conditions and surroundings. These aggregations of plants which are adapted to similar conditions are known as **plant societies.**

358. Moisture and temperature are the leading factors in determining plant societies. The great geographical societies or aggregations of the plant world are for convenience associated chiefly with the moisture supply. These are: (1) **hydrophytic** or **wet-region societies,** comprising aquatic and bog vegetation (Fig. 369); (2) **xerophytic** or **arid-region societies,** comprising desert and most sand-region vegetation (Fig. 344); (3) **mesophytic** or **mid-region societies,** comprising the vegetation in intermediate regions (Fig. 370). Mesophytic vegetation is characteristic of most regions which are fitted for agriculture. The **halophytic** or **salt-loving societies** are also distinguished, comprising the seashore and salt-area vegetation (Fig. 371). Much of the characteristic scenery of any place is due to its plant societies (337). Xerophytic plants usually have small and hard leaves, apparently to prevent too rapid transpiration. Usually, also, they are characterized by stiff growth, hairy covering, spines, or a much-contracted plant-body, and often

by large underground parts for the storage of water. Halophytic plants are often fleshy.

359. Plant societies may also be distinguished with reference to latitude and temperature. There are **tropical societies, temperate-region societies, boreal** or **cold-region societies.** With reference to altitude, societies might be classified as **lowland** (which are chiefly hydrophytic), **intermediate** (chiefly mesophytic), **subalpine** or **mid-mountain** (which are chiefly boreal), **alpine** or **high-mountain.**

371. A seashore society, of sand dune plants. New Jersey.

360. The above classifications have reference chiefly to great geographical floras or societies. But there are societies within societies. *There are small societies coming within the experience of every person who has ever seen plants growing in natural conditions.* There are roadside, fence-row, lawn, thicket, pasture, dune, woods, cliff, barnyard societies. **Every different place has its characteristic vegetation.** Note the smaller societies in Figs. 369

and 370. In the former is a water-lily society and a cat-tail society. In the latter there are grass and bush and woods societies.

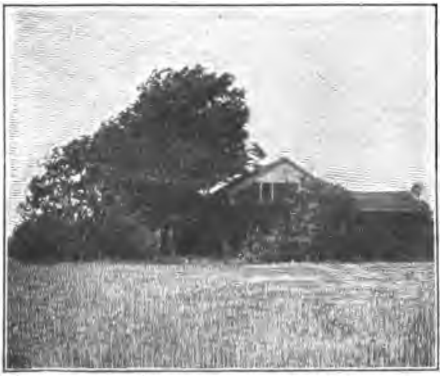
372. A colony of weeds in a barnyard.

361. **SOME DETAILS OF PLANT SOCIETIES.**—Societies may be composed of **scattered and intermingled plants,** or of dense **clumps or groups of plants.** Dense clumps or groups are usually made up of one kind of plant, and they are then called **colonies.** Fig. 372. Colonies of most plants are transient: after a short time other plants gain a foothold amongst them, and an intermingled society is the outcome. Marked exceptions to this are grass colonies and forest colonies, in which one kind of plant may hold its own for years and centuries.

373. The beginning of a forest on a lawn.
Grass and weeds, and here and there a young bush and a forest tree.
The border is already forested.

374. The return to forest. Bushes and trees now begin to crowd.

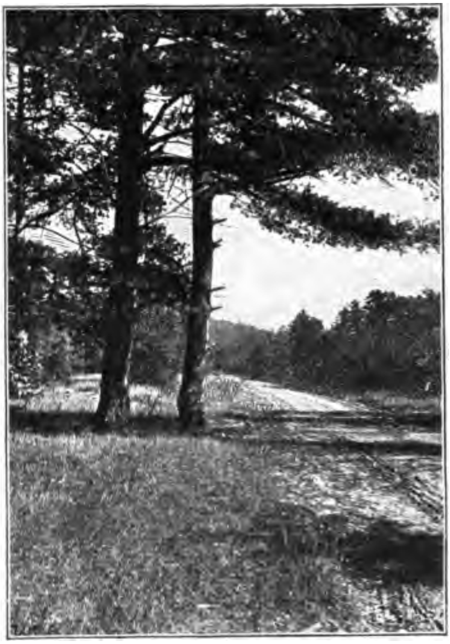
362. In a large newly cleared area plants usually **first establish themselves in dense colonies.** Note the great patches of nettles, jewel-weeds, smart-weeds, clotburs, fire-weeds in recently cleared but neglected swales, also the fire-weeds in recently burned areas, the rank weeds in the neglected garden, and the ragweeds and May-weeds along the recently worked highway. The competition amongst themselves and with their neighbors finally breaks up the colonies, and *a mixed and intermingled flora is generally the result.*



375. Sod and tree societies. About the building the trees find refuge from the mowing machine.

363. In most parts of the world the **general tendency of neglected areas is to run into forest.** All plants rush for the cleared area. Here and there bushes gain a foothold. Young trees come up: in time these shade the

bushes and gain the mastery. Sometimes the area grows to poplars or birches, and people wonder why the original forest trees do not return; but these forest trees may be growing unobserved here and there in the tangle, and in the slow processes of time the poplars perish—for they are short-lived — and the original forest may be replaced. Whether one kind of forest or another returns will depend largely on the kinds which are most seedful in that vicinity and which, therefore, have sown themselves most profusely. Much depends, also, on the kind of undergrowth which first springs up, for some young trees can endure more or less shade than others. Figs. 373 and 374 show two stages in the return to forest.



376. The farmer mows part of his roadside.

364. **Pasturing and mowing tend to keep an area in grass.** This is because the grass will thrive when the tops are repeatedly taken off, whereas trees will not. Note that the wild herbs and bushes and trees persist along the fences and about old buildings, where animals and mowing machines do not take them off. *A sod society means grazing or mowing.* Consider Figs. 96, 375, 376. The farmer

keeps his wild pastures "clean" by turning in sheep: the sheep are fond of browsing.

377. An aquatic society in which several kinds of plants grow side by side.

365. Some plants **associate.** They grow together. This is possible largely because they diverge or differ in character (352). Plants associate in two ways: *by growing side by side; by growing above or beneath.* In sparsely populated societies (as in Fig. 377) plants may grow along-side each other. In most cases, however, there is **overgrowth** and **undergrowth:** one kind grows beneath another. Plants which have become adapted to shade (354) are usually undergrowths. In a cat-tail swamp (Fig. 378), grasses and other narrow-leaved plants grow in the bottom, but they are usually unseen by the casual observer. Search the surface of the ground in any swale or in a meadow. Note the undergrowth in woods or under trees (Fig. 379). Observe that in pine and spruce forests there is almost no undergrowth, because there is very little light. Fig. 362.

378. Grasses and narrow-leaved plants grow between the cat-tail flags.

366. On the same area the societies may **differ at**

different times of the year. There are spring, summer, and fall societies. The knoll which is cool with grass and strawberries in June may be aglow with goldenrod in September. If the bank is examined in May, look for the young plants which are to cover it in July and October; if in September, find the dead stalks of the flora of May. What succeeds the skunk cabbage, hepaticas, trilliums, phlox, violets, buttercups of spring? What precedes the wild sunflowers, ragweed, asters, and goldenrod of fall?

367. In lands which gradually rise from wet to dry, the societies may take the form of **belts or zones.** Starting at a shore, walk back into the high land; note the changes in the flora. Three zones are shown in Fig. 380.

368. To a large extent the **color of the landscape** is determined by the character of the plant societies. Evergreen societies remain green, but the shade of green varies from season to season; it is bright and soft in spring, becomes dull in midsummer and fall, and usually assumes a dull yellow-green in winter. Deciduous societies vary remarkably in color—from the dull browns and grays of winter to the brown-greens and olive-greens of spring, the staid-greens of summer, and the brilliant colors of autumn. The **autumn colors** are due to intermingled shades of green, yellow and red. The coloration varies with the kind of plant, the special location, and the season.

379. **Overgrowth and undergrowth in three series, —trees, bushes, grass.**

Even in the same species or kind, individual plants differ in color; and this individuality usually distinguishes the plant year by year. That is, an oak which is maroon-red this autumn is likely to exhibit that color every year. The autumn color is associated with the natural maturity and death of the leaf, but it is most brilliant in long and open falls — largely because the foliage ripens more gradually and persists longer in such seasons. It is probable that the autumn tints are of no utility to the plant. The yellows seem to be due to the breaking down and disorganization of the chlorophyll. Some of the intermediate shades are probably due to the unmasking or liberating of normal cell color-bodies which are covered with or obscured by chlorophyll in the growing season. The reds are due to changes in the color of the cell sap. Autumn colors are not caused by frost. Because of the long, dry falls and the great variety of plants, the autumnal color of the American landscape is phenomenal.

380. Three society zones—bog, forest rim, forest.

369. **ECOLOGY.**—The study of the relationships of plants and animals to each other and to seasons and environments is known as **ecology** (still written *œcology* in the dictionaries). All the discussions in Part II of this

book are really different phases of this subject. It considers the habits, habitats, and modes of life of living things—the places in which they grow, how they migrate or are disseminated, means of collecting food, their times and seasons of flowering, producing young, and the like.

REVIEW.—What is a plant society? Why do plants grow in societies? Name societies that are determined chiefly by moisture. What societies are most abundant where you live? Name those determined by latitude and altitude. Name some small or local societies. What are colonies? Where are they most marked? Why do they tend finally to break up? How are societies made up when colonies are not present? How do forests arise on cleared areas? What effect have pasturing and mowing? How do plants associate? What is undergrowth and overgrowth? Explain how societies may differ at different times of the year. What are zonal or belt societies? Discuss autumn colors. What is ecology?

NOTE.—One of the best of all subjects for school instruction in botany is the study of plant societies. It adds definiteness and zest to excursions. Let one excursion be confined to one or two societies. Visit one day a swamp, another day a forest, another a pasture or meadow, another a roadside, another a weedy field, another a cliff or ravine, etc. Visit shores whenever possible. Each pupil should be assigned a bit of ground—say 10 or 20 ft. square—for special study. He should make a list showing (1) how many kinds of plants it contains, (2) the relative abundance of each. The lists secured in different regions should be compared. It does not matter if the pupil does not know all the plants. He may count the kinds without knowing the names. It is a good plan for the pupil to make a dried specimen of each kind for reference. The pupil should endeavor to discover why the plants grow as they do. *Challenge every plant society.*

Everyone should learn to grow plants.

CHAPTER XXX

VARIATION AND ITS RESULTS

370. **THE FACT OF VARIATION.—No two plants are alike** (16). In size, form, color, weight, vigor, productiveness, season, or other characters, they differ. The most usual form of any plant is considered to be its **type,** that is, its representative form. Any marked departure from this type is a **variation,** that is, a difference.

371. **THE KINDS OF VARIATIONS.—Variations are of many degrees.** The differences, in any case, may be so slight as to pass unnoticed, or they may be so marked as to challenge even the casual observer. If a red-flowered plant were to produce flowers in different shades of red, the variation might not attract attention; but if it were to produce white flowers, the variation would be marked. Whenever the variation is so marked and so constant as to be worth naming and describing, it is called a **variety** in descriptive botany. If the variation is of such character as to have value for cultivation, it is called an **agricultural** or **horticultural variety.** There is no natural line of demarcation between those variations which chance to be named and described as varieties and those which do not. Varieties are only named variations.

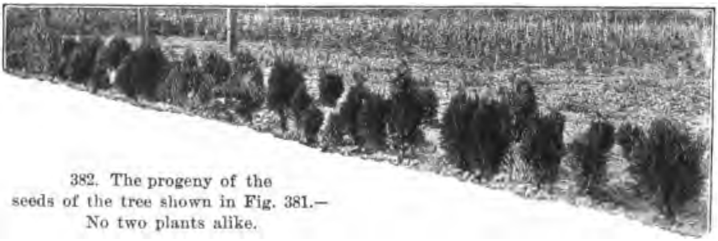
372. Variations may arise in three ways: (1) directly from **seeds;** (2) directly from **buds;** (3) by a slow **change of the entire plant after it has begun to grow.**

373. Variations arising from seeds are **seed-variations;** those which chance to be named and described are **seed-varieties.** Never does a seed exactly reproduce its parent: if it did, there would be two plants alike. Neither do any

two seeds, even from the same fruit, ever produce plants exactly alike. Even though the seedlings resemble each other so closely that people say they are the same, nevertheless they will be found to vary in size, number of leaves, shape, or other features. Figs. 381 and 382 illustrate seed-variation.

381. An arbor-vitæ tree, from which seeds were taken one day.

374. Variations arising directly from buds, rather than from seeds, are **bud-variations**, and the most marked of them may be described and named as **bud-varieties.** We have learned in Chapter V how the horticulturist propagates plants by means of buds: not one of these buds will reproduce exactly the plant from which it was taken. We have already discovered (17, 118) that no two branches are alike, and every branch springs from a bud. Bud-variation is usually less marked than seed-variation, however; yet now and then one branch on a plant may be so unlike every other branch that the horticulturist selects buds from it and endeavors to propagate it. "Weeping" or pendent branches sometimes appear on upright trees; nec-


382. The progeny of the seeds of the tree shown in Fig. 381.—No two plants alike.

tarines sometimes are borne on one or more branches of a peach tree, and peaches may be borne on nectarine trees; russet apples are sometimes borne on Greening apple trees; white roses are sometimes found on red-flowered plants.

375. Frequently a plant **begins a new kind of variation long after birth,** even after it has become well established. It is on this fact that successful agriculture depends, for the farmer makes his plants better by giving them more food and care: and betterment (like deterioration) is only a variation as compared with the average plant. Plants which start to all appearances equal may end unequal: some may be tall and vigorous, others may be weak, others may be dwarf: some will be worth harvesting and some will not.

376. **THE CAUSES OF VARIATIONS.**—*Variations are due to several and perhaps many causes.* One class of causes lies in the **environment,** and another lies in the **tendencies derived from parents.** Of the environmental causes of variation, the chief is **food supply.** Good agriculture consists largely in increasing the food supply for plants—by giving each plant abundant room, keeping out competing plants, tilling the soil, adding plant-food. Fig. 383. Another strong environmental factor is **climate** (Chapter XXVII). It is very difficult to determine the exact causes of any variation. There is much difference of opinion respecting the causes of variation in general. The extent of variation due to food supply is well illustrated in Fig. 383. The two pigweeds grew only five feet apart, one in hard soil by a walk, the other near a compost pile. They were of similar age. One weighed ½ oz.; the other 4¼ lbs., or 136 times as much.

377. **HEREDITY.**—Marked variations **tend to be perpetuated.** That is, offspring are likely to retain some of the peculiarities of their parents. This passing over

of characteristics from parent to offspring is **heredity.** By "selecting the best" for seed the farmer maintains and improves his crops. It is said that "like produces like." This is true of the general or average features, but we have seen that the reproduction is not exact. It is truer to say that similar produces similar. Fig. 384 represents a marked case of heredity of special characters. The plants on the right grew from a parent 24 in. high and 30 in. broad. Those on the left grew from one 12 in. high and 9 in. broad. (For a history of these parents see "Survival of the Unlike," p. 261.)

383. Variation.—Big and little pigweeds of the same kind.

378. **SELECTION.**—There is intense struggle for existence: there is universal variation: **those variations or kinds live which are best fitted to live under the particular conditions.** This persistence of the best adapted and loss of the least adapted is the process designated by Darwin's phrase "natural selection" and by Spencer's "survival of the fittest." Natural selection is also known as Darwinism.

379. By a similar process, the cultivator modifies his plants. He chooses the variations which please him, and from their offspring constantly selects for seed-bearing those which he considers to be the best. In time he has a new variety. **Plant-breeding** consists chiefly of two things: **producing a variation in the desired direction; selecting,** until the desired variety is secured.

380. **EVOLUTION.**—Variation, heredity, natural selection, and other agencies bring about a *gradual change in the plant kingdom;* this change is **evolution.** The hypothesis that one form may give rise to another is now universally accepted amongst investigators; but whether the vegetable kingdom has all arisen from one starting point is unknown. Only a few of the general lines of the unfolding of the vegetable kingdom, with numberless details here and there, have been worked out. Not every form or kind of plant can be expected ever to vary into another kind. Some kinds have nearly run their course and are undergoing the age-long process of extinction. It is believed, however, that every kind of plant now living has been derived from some other kind. Evolution is still in progress. *Variation and heredity are the most important facts in organic nature.*

384. The progeny of little and big plants.

REVIEW.—What is a variation? A variety? Agricultural variety? How may variations arise? Explain each of the three categories. What are some of the causes of variation? What is heredity? Selection? What are essentials in plant-breeding? What is evolution?

PART III—HISTOLOGY, OR THE MINUTE STRUCTURE OF PLANTS

CHAPTER XXXI

THE CELL

381. **THE CELL AS A WHOLE.**—All of the higher plants are made up of a large number of bodies or parts called **cells.** *These are so minute that, in most cases, they are invisible to the naked eye.*

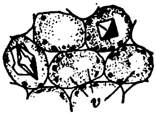
382. **CELLS ARE OF MANY FORMS.**—In general, plant cells may be assigned to some one of the following forms:

spherical, as in protococcus (a minute alga to be found on damp walls and rocks), and apple flesh;
polyhedral, or many-sided, as in pith of elder;
tabular or **flat,** as in epidermis of leaves;
cylindrical, as in vaucheria, spirogyra;
fibrous, as cotton fibers;
vascular, as the ducts of wood;
stellate, as in the interior of leaves of lathyrus (sweet pea) and other plants.

383. **PARTS OF A CELL.**—Every living, growing cell contains **protoplasm** (171), a colorless, semi-fluid substance, which is usually inclosed within a **cell-wall.** Within the wall, also, and sometimes closely surrounded by protoplasm, is a dense body known as the **nucleus.** The nucleus usually contains a smaller **central part,** or

nucleolus. Cell-walls are so often absent that it is quite as well to think of a cell as a single nucleus with its attendant protoplasm. The nucleus is an essential part of every cell, and is intimately connected with the wonderful process of cell-division. In some very low forms of plants, as in some of the bacteria, no nucleus has yet been clearly made out.

384. **NATURE OF PROTOPLASM.—Protoplasm, with its nucleus, forms the essential part of all living, acting cells.** It is possible in many cases to find a small mass of living protoplasm *with a nucleus but without a cell-wall.* Protoplasm is not entirely homogeneous, for when examined with a microscope of very high power it is often found to be of a foamy or honeycomb nature. This mesh or network contains many minute granules, called **microsomes,** and lies in a clear "ground mass" composed of cell-sap. On a glass slip mount in a drop of water some compressed or brewer's yeast which has been growing in a thin syrup of white sugar for twenty-four hours; place over the drop a thin cover-glass, and examine with the compound microscope, first with the low power and then with the high. The individual cells should be visible. Note the shape and contents of the cells, and make a sketch of a few of them. A similar study may be made of the soft pulp scraped from a celery stem; of hairs scraped from the surface of a begonia leaf; of threads of spirogyra; cells of protococcus; soft white cells of an apple; the thin leaves of various mosses; the epidermis of waxy plants.



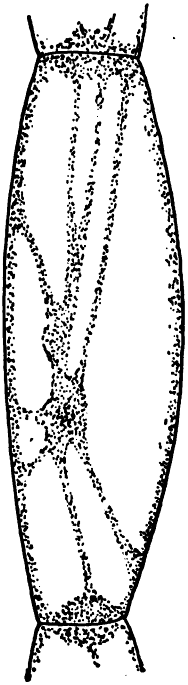
385. Cells in petiole of begonia leaf. Vacuoles at *v.* Two cells contain crystals of calcium oxalate.

385. **VACUOLES.**—Protoplasm often does not entirely fill the cell. There may be a number of **cavities** or **vacuoles** in a single cell. These vacuoles are filled with *cell-sap* (*v.*, Fig. 385). In some parts as in buds and root-tips, where the cells are most

actively dividing, the protoplasm may entirely fill the space and no vacuoles be present.

386. **MOVEMENTS OF PROTOPLASM.**—Within the cell-wall, many times the *protoplasm shows a tendency to move from place to place.* This movement is chiefly of two kinds: (1) **circulation,** or movement not only along the walls but also across the cell-body, as seen in the long, thin-walled cells of celandine; in the staminal hairs of tradescantia (Fig. 386); in the bristles of squash vines; in the stinging hairs of nettle; in stellate hairs of hollyhock. (2) **rotation,** or movement along the walls only, well seen in the cells of many water plants, as elodea, chara, and nitella (Fig. 387).

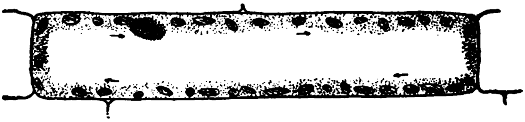
387. Besides these and other movements of protoplasm within the cell-wall, there are also *movements of naked protoplasm,* of two main types: (1) **amœboid or creeping movements,** such as may be seen in a plasmodium of myxomycetes, or in an amœba; (2) **swimming by means of cilia or flagella,** illustrated in the swarm-spores of water fungi, and of some algæ, and in motile bacteria. By the last type of movement the unicellular bodies (swarm-spores and bacteria) are often moved very rapidly. To see movement in protoplasm, carefully mount in water a few hairs from the stamens of tradescantia (spider-wort). The water should not be too cold. Examine with a power high enough to see the granules of protoplasm. Make a sketch of several cells and their contents. It may be necessary to make several trials before success is attained



386. Circulation of protoplasm in a cell of a stamen hair of tradescantia or spider-wort. Magnified 600 times.

in this experiment. If the microscope is cold, heat the stage gently with an alcohol lamp, or by other means; or warm the room. See Fig. 386.

388. **NATURE OF CELL-WALL.**—The cell-wall of very young cells is **a delicate film or membrane.** As a cell grows in size the wall remains thin and does not begin to thicken until the cell has ceased to enlarge. The fundamental substance of cell-walls is a carbohydrate known as *cellulose.* The cellulose generally stains blue with hematoxylin. Often by incrustations or deposits of one kind or another, the cellulose reaction is lost or obscured. Two of the most common additions are *lignin*, forming wood, and *suberin*, forming cork. The walls then are said to be lignified or suberized.



387. Rotation of protoplasm in Elodea Canadensis (often known as Anacharis). Common in ponds.

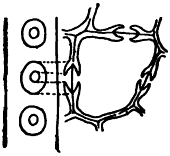
389. In all the cells studied in the above experiments the *walls are thin and soft.* In general, those cells which have thin walls are called **parenchymatous cells.** Some cells, as those of nuts and the grit of pear fruit, have *very thick walls*, and are called **sclerenchymatous** cells. In many cases the cell-walls are intermediate between these extremes.

390. Cell-walls often *thicken* by additions to their *inner* surface. This increase in thickness *seldom takes place uniformly in all parts.* Many times the wall remains thin at certain places, while the most of the wall becomes very thick. Again the walls may thicken very much in angles or along certain lines, while most of the wall remains thin. As a result of this uneven thickening

the walls of cells take on certain definite **markings.** Some of the names applied to these markings are:

Pitted, with little holes or depressions, forming very thin places, as seen in seeds of sunflower, and in the large vessels in the stem of the cucumber.

Bordered pits, when the pits are inclosed in the cell-wall, as in wood of pines and other conifers. Fig. 388.

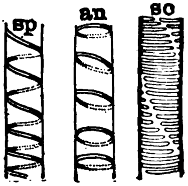

388. Bordered pits in pine wood.

Spiral, with the thickening in a spiral band, as in the primary wood of most woody plants and in the veins of leaves. Fig. 389.

Annular, with thickening in the form of rings; seen in the large vessels of the bundles in stem of Indian corn. Fig. 389.

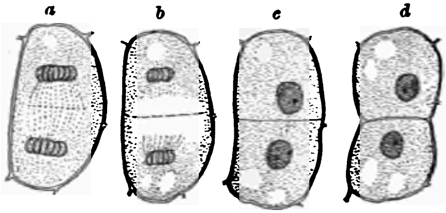
Scalariform, with elongated thin places in the wall, alternating with the thick ridges which appear like the rounds of a ladder. Fig. 389. These are well shown in a longitudinal section of the root of the brake fern (Pteris).

391. **MULTIPLICATION OF CELLS.—Cells give rise to new cells.** Thus does the plant grow. The most common method by which cells are multiplied is that called **cell division.** A modified form of cell division is called **budding. Cell division is a process by which two (or more) cells are made from one original cell.** *Cells which have an abundance of protoplasm are usually most active in cell division.* The process is *at first an internal one.* The nucleus gradually divides into two masses and the protoplasm of the cell is apportioned between these two nuclei; a new cell-membrane, or partition wall, is usually thrown across and the cell is completely



389. Markings in cell-walls. *sp*, spiral; *an*, annular; *sc*, scalariform.

divided into two cells. Fig. 390. In some cases, however, the nucleus divides many times without the formation of a cell-wall. The cell which began to divide is called the **mother cell,** and the resulting cells are **daughter cells.**



390. Four steps in process of cell-division. Mother cell at left, far advanced in division; daughter cells at right.

392. **Cell budding** is a variety of cell division in which **the cell is not divided in the middle.** The mother cell pushes out a protuberance, which becomes *separated by a constriction of the walls.* Cells of the yeast plant and the spores of many fungi multiply in this way.

393. In no case, so far as we yet know, can the cell divide without a division of the nucleus and the protoplasmic mass. There are two methods of nuclear division: (1) **direct,** as found in the old cells of nitella, tradescantia, and others, in which the mass of the nucleus divides by simple constriction; (2) **indirect,** as found in all actively growing tissue, in pollen grains, spores, etc. There are several stages in the latter process. The nucleus divides in intricate methods, giving rise to odd forms known as *nuclear figures.* **Mitosis** and **karyokinesis** are names sometimes given to indirect nuclear division. The study of this process is a very difficult one, as it requires a very high power microscope to see the different stages. They are easily seen in cells found in buds of convallaria and in pollen grains of that plant, but may be studied in all plants. The process is too difficult for the beginner to trace, but it is outlined in the note on next page. Fig. 390 is not intended to represent all the stages in indirect nuclear division.

REVIEW.— What are some of the forms of cells? Name the parts of a living cell. What part or parts are essential in all cases? Give your idea of the nature of protoplasm. What differences did you find between the cells of yeast and those of green alga? In what ways do they resemble each other? Tell the same of cells of protococcus and of apple, or of other material studied. What is a vacuole? What does it usually contain? Name two kinds of movements of protoplasm within the cell-wall, and explain how each may be observed. Name and describe two movements of naked protoplasm. Tell something of the texture of cell-walls. What causes the markings found on cell-walls? Name five types of markings. Draw two figures to show structure of bordered pits. Make a sketch of spiral, annular, and scalariform markings. Name two methods of cell-multiplication. Describe the process of cell-division. How does cell-budding differ from cell-division? Name two methods of nuclear division. Which is the more common method?

NOTE TO PARAGRAPH 393.—Karyokinesis (the indirect or mitotic process of nuclear division) is an intricate subject. The details vary in different plants, but the essential stages are as follows:

During the resting stage the nucleus is surrounded by a very delicate but distinct membrane. Within this inclosure is an intricate network of colorless (*linin*) threads bearing very numerous granules, which in stained preparations are highly colored, and for this reason have received the name *chromatin*. The network is surrounded by nuclear-sap, and often incloses within its meshes a large body called the *nucleolus*. As the time for division approaches the chromatin network changes into a definite, much-coiled, deeply stained ribbon, in which the granular structure is much less noticeable, and this in turn segments transversely into a number of parts called *chromosomes*. The prctoplasmic fibrils immediately surrounding the nucleus now gradually converge towards two points lying on opposite sides of the nucleus and at a slight distance from the membrane. This is accomplished in such a way that a spindle of nearly colorless threads is produced, with the two previously mentioned points of convergence acting as poles. Meanwhile both the nuclear membrane and the nucleolus have disappeared, but whether these structures take part in the formation of the spindle is yet an open question. Radiations of protoplasmic threads called *asters* sometimes occur around the poles, and in a few lower plants, as well as in most animals, the pole is occupied by a small spherical body termed a *centrosphere*. The steps so far are known as the *prophase* stages. The chromosomes now move to the equator of the spindle, where they arrange themselves in a definite manner, forming the so-called *nuclear-plate* (*metaphase* stage). Each segment splits longitudinally, apparently on account of the contractive action of the spindle fiber to which it is attached; and one daughter-segment passes to each pole (*anaphase* stage). Each of the two groups of daughter-segments very soon becomes surrounded by a new membrane, the chromosomes gradually fuse end to end, the nucleolus reappears, and at length two resting nuclei are produced similar in every respect to the parent nucleus (*telophase* stage). Meanwhile each spindle fiber becomes swollen at the equator, thus producing a series of dots all arranged in one plane. These at length fuse, forming a delicate transverse cell-membrane, which by the peripheral expansion of the spindle at length reaches the lateral walls, and cell-division is thus complete. This process of indirect nuclear division is one of the most wonderful phenomena yet discovered in organic development, not only on account of its intricacy and beauty, but also because it has been found that hereditary characteristics are in all probability transmitted solely through the chromosomes. The longitudinal division and separation seem to be for the purpose of insuring equal apportionment of the hereditary substance to each daughter-nucleus. The subject, however, is still in its infancy, and authors disagree both as to details and as to theoretical considerations.

NOTE ON SCOPE, APPARATUS, AND METHODS.—The work outlined in Part III is sufficient, if well donė, to occupy one period of the pupil's time each school day for six weeks. These chapters are intended only as *laboratory guides*. The pupil should work out each structure or part for himself before taking up the succeeding subject. The work in this Part deals with only the elements of the subject, but it is as much as the high school pupil can hope to take up with profit.

Apparatus.—The apparatus necessary for the work outlined in these chapters on histology may be obtained from dealers in microscopes and laboratory supplies at a low figure. Schools should obtain catalogues from the following and other reliable dealers:

Bausch & Lomb Optical Co., Rochester, N. Y.
Eimer & Amend, New York.
The Franklin Educational Co., Boston.
Queen & Co., Philadelphia.
Richards & Co., Chicago and New York.
Spencer Lens Co., Buffalo.
Williams, Brown & Earle, Philadelphia.
Geneva Optical Co., Chicago.
Whitall, Tatum & Co., New York.
Chas. Lentz & Sons, Philadelphia.
Richard Kny & Co., New York.
Cambridge Botanical Supply Co., Cambridge, Mass.

The microscope should have a one-inch and perhaps a two-inch eye-piece and two objectives of say $\frac{2}{3}$- and $\frac{1}{6}$-inch focal lengths. By arranging the laboratory study of the pupils at different times each microscope may be used by three, four, or even more pupils.

There should be a microtome or section-cutter for use by the class.

Each pupil should have his own individual tools and bottles of reagents, as follows:

1 good razor (hollow-ground on one side only),
1 small scalpel,
1 pair forceps,
2 sharp needles mounted in handles (as penholders) (Fig. 199),
1 medicine dropper,
1 small camel's hair brush,
A number of slides and cover-glasses.

Of reagents, stains, and other chemicals, there should be the following:

Glycerine,
Ninety-five per cent alcohol,
Formalin (40 per cent formaldehyde).
Clearer (made of three parts turpentine and two parts melted crystals of carbolic acid),
Canada balsam,
Ether,
2 per cent and 5 per cent collodion,
Iodine dissolved in water,
" " " alcohol,
Hematoxylin,
Copper sulfate solution,
Potassium hydroxide solution,
Fehling's solution (see paragraph 397),
Alcanin (henna root in alcohol).

The two per cent collodion is made of forty-nine parts alcohol, forty-nine parts ether, two parts soluble cotton. This strength is suitable to use in sticking sections to the glass slide to prevent their escape during the staining and clearing process. It need not be used unless desired. Collodion is often useful for imbedding material, as indicated under the head "Imbedding" on page 243. Pupils must exercise great care in using carbolic acid, as it burns the flesh.

Hematoxylin stain may be obtained of dealers in a condition ready for use, or may be prepared by this recipe (*Gage's Hematoxylin*): Distilled water 200 cc. and potash alum 7½ grams, boil together for five minutes in glass dish or agate ware. Add enough boiled water to bring the volume back to 200 cc. When cool add 4 grams of chloral hydrate and $\frac{8}{10}$ gram of hematoxylin crystals which have been dissolved in 20 cc. of ninety-five per cent alcohol. This is quite permanent, and becomes of a deeper color after standing for some time if left in a light place and frequently shaken. It stains the tissues which bear protoplasm and cellulose walls, causing them to stand out in contrast with the other tissues.

Preparing and Keeping Laboratory Material.—In preparing material for the experiments outlined in Part III., the pupil or teacher will find it best to get much of the material during the growing season and preserve it until the time for use. Soft material should be dehydrated and hardened by placing it in about 40 per cent alcohol for several hours to two days, according to its size, and then placing it in about 70 per cent for the same length of time. It can then be placed in 80 per cent alcohol, and is ready for use at any time. When thus preserved, the tissues containing protoplasm are sometimes much shrunken. For this reason it is well to preserve some of the material in a liquid containing a great deal of water. One of the best liquids is a 2 per cent or 2½ per cent solution of formalin. This preserves material well but does not dehydrate it. Formalin burns the flesh.

Free-hand Cutting and Mounting.—To cut sections, the material may often be held between pieces of pith or smooth cork in the microtome or fingers. The material and sections should be kept wet with alcohol during the time of cutting.

The sections when cut should be wet in water, then stained with hematoxylin for a few minutes; drain off the hematoxylin and rinse with water; then use ninety-five per cent alcohol to extract all the water from the sections; then pour on clearer for a few minutes. Put a drop of Canada balsam on the sections, and they are ready for the thin cover glass. Mounts thus made are permanent.

Some reasons for the steps in the process may be understood from the fact that hematoxylin does not mix readily with alcohol, and balsam does not mix with water nor with alcohol. Sections mounted before they are freed from water become cloudy and worthless.

Fixing and Microtome Sectioning.—For the purpose of preparing permanent miscroscopic sections of leaves, wood, or any other plant-tissues, select typical specimens of the part desired and cut them into pieces as small as can be conveniently handled. These may then be prepared by the following processes:

1. Fixing: If the material is to be used simply for the study of tissue-arrangement, cell-structure, etc., the treatment with alcohol described in the paragraph relating to the preparing and keeping of laboratory material is sufficient preparation for the imbedding process. Protoplasmic structures, however, are likely to be distorted or disintegrated after this treatment, due to the slow process of killing. Some method of quickly killing or "fixing" the protoplasm is therefore necessary. With hematoxylin staining only a few methods are available, among which the following is perhaps the best. Cut the fresh material into very small pieces (the smaller the better) and drop into so-called absolute alcohol (96 per cent or stronger); after a few hours preserve in 90 or 95 per cent alcohol. With other stains more accurate fixing agents may be used, such as chromic acid, osmic acid, acetic acid, etc., either separately or in combination. The treatment, however, is in these cases rather complicated.

2. Imbedding: The pieces must be imbedded in some substance in which they can be held and sectioned. For this purpose collodion is generally used. Pour off the alcohol, and add enough 2 per cent collodion to cover the material about three-fourths of an inch. After twenty-four hours this may be poured back into the stock bottle, and an equal amount of 5 per cent collodion put on the material. The collodion contains ether and alcohol, both of which are volatile; therefore these operations must be performed as quickly as possible, and the corks of collodion bottles should always be sealed by holding the bottle neck down for a few seconds. Leave the material in 5 per cent collodion twenty-four hours, and then pour the contents of the vial into a paper box, which may be made by folding a piece of writing paper. The size of the box must be judged so that each piece of material will be surrounded by a quantity of collodion, and the inside of the box should be greased with vaseline to prevent the collodion from sticking. The pieces will sink to the bottom, where they may be arranged with a needle. If there is not enough collodion in the box add some from the stock bottle. The box should then be placed in a shallow vessel on the bottom of which a little alcohol has been poured, and covered with a pane of glass leaving a very small opening on one side. In about twenty-four hours the collodion will have hardened into a cake having the consistency of cheese. The material may now be cut into small blocks and stored in 85 per cent alcohol.

3. Cutting: For cutting sections, either a hand microtome or a

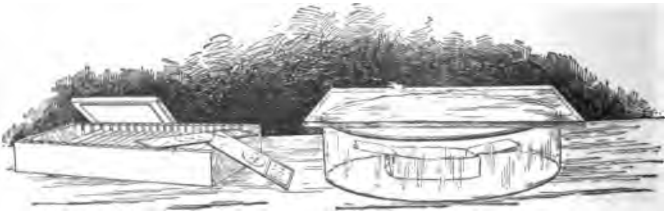
small sliding microtome and a sharp razor are necessary. Cut one of the pieces of collodion into an oblong block with the imbedded material near one end. This can be clamped in the microtome, being held in place by a flat piece of cork on either side. The collodion must project above the cork. The razor should be adjusted in such a manner that the whole length of the blade is used in cutting. The blade should be tilted downwards so that only the cutting edge comes in contact with the block which should not be scraped by the lower flat surface of the razor back of the edge. Both the collodion block and the razor must be kept flooded with alcohol during the process of cutting. When several sections have been cut they may be floated out on a slide and arranged near the center. Then with a pipette place a drop of ether on the sections. This partially dissolves the collodion and thus sticks the sections to the slide. The slide is then covered with water to remove the alcohol, after which it is ready for staining. Sections are ruined if allowed to become dry at any time after cutting.

4. Stain with hematoxylin for from three to five minutes, and wash off the surplus stain with water.

5. Drain off the water and dehydrate by keeping the slide flooded with alcohol for ten minutes, or by placing it in a vessel of alcohol.

6. Pour off the alcohol and cover the slide with a clearing mixture (see p. 241) and allow it to stand for ten minutes. The clearer removes the alcohol which cannot mix with balsam.

7. Drain and wipe off as much of the clearer as possible without touching the sections. Then place a small drop of prepared Canada balsam on the sections near the center of the slide, and with a pair of forceps lay on a clean cover-glass. If the proper amount of balsam has been used it will spread out to the edge of the cover-glass without exuding. The slide is now ready to be examined. It should be cleaned and labelled and put away in a small wooden box which is furnished by dealers in microscopical supplies.



Box of microscope slides, and a packet of collodion drying in a glass vessel.

CHAPTER XXXII

CONTENTS AND PRODUCTS OF CELLS

394. **THE LIVING CELL IS A LABORATORY.**—In nearly all cells are found one or more non-protoplasmic substances which are produced by the plant. Some of these are very useful to the plant, and others seem to be discarded or excretory products. There is considerable **division of labor** among the cells of higher plants, one cell or group of cells producing one product and another cell producing another product.

395. **CHLOROPHYLL.** — Cells may contain **chlorophyll bodies** if they are exposed to the sunlight. Chlorophyll is a green substance infiltrated in a protoplasmic ground-mass. It imparts color to all the green parts of the plant. Its presence is absolutely necessary in all plants which have to secure their nourishment wholly or in part from the air and from mineral matter of soil. Review Chapter XII. Most parasites and saprophytes do not bear chlorophyll, but live on organic matter (Chapter XIII). The oval bodies in the cell of Figs. 411, 413, 414, are chlorophyll bodies.

396. **CELL-SAP.**—Often the most abundant of the different cell-contents is **cell-sap.** It may contain a number of different substances, many of which are in solution and can be detected by the use of chemical reagents. Some of these substances are:

Sugar,
- *milk* (lactose).
- *grape* (glucose or dextrose, $C_6H_{12}O_6$).
- *fruit* (levulose).
- *cane* (saccharose, $C_{12}H_{22}O_{11}$).
- *malt* (maltose).

Inulin, which takes the place of starch in compositæ and others.

Fats and oils, as in flaxseed and castor bean.

Mucus or **mucilage**, as in orchid roots, onions, quince seed, ducts of some plants, as cycads.

Tannins, as in oak, hemlock bark, and many other plants.

Alkaloids,
- *Atropin*, in belladonna.
- *Nicotin*, in tobacco.
- *Emetin*, in ipecac root.
- *Caffein*, in coffee.
- *Strychnin*, in nux vomica.
- *Morphin*, in Papaver somniferum (opium poppy).
- *Quinin*, in cinchona or Peruvian bark tree.

Resins, as in Coniferæ.

Gum-resins, **Caoutchouc**, as in India-rubber plant.

Vegetable acids,
- *Formic*, as in stinging nettles.
- *Acetic*, as in fermented cider.
- *Oxalic*, mostly in form of calcium oxalate (see crystals, Fig. 385).
- *Malic*, as in apple.
- *Citric*, as in lemon.
- And many others.

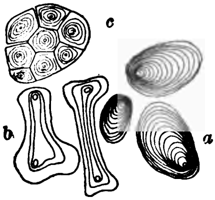
397. **Sugar** is found in almost all parts of the plant and at all periods of growth. In a few it is crystallized, as in date-seeds, squills, and others. Sugar serves as a *reserve material* in such plants as beet, cane, corn, onion. Being readily soluble, sugar is a convenient form for the *transportation of the food store* from one part of the plant to another, as from leaves to roots during the fall season and from roots to stems and leaves during the spring season. It results from the digestion of starch (168). See note p. 251. Sugar in fruits attracts many animals, and in

nectar of flowers it attracts insects. *To test for glucose:* Make a thick section of a bit of the edible part of a pear and place it in a bath of Fehling's solution. After a few moments boil the liquid containing the section for one or two minutes. It will turn to an orange color, showing a deposit of an oxide of copper and perhaps a little copper in the metallic form. A thin section treated in like manner may be examined under the microscope, and the fine particles, precipitated from the solution by the sugar of the pear, may be clearly seen. (Fehling's solution is made by taking one part each of these three solutions and two parts of water: (1) Copper sulfate, 9 grams in 250 c.c. water; (2) sodium hydroxide, 30 grams in 250 c.c. water; (3) rochelle salts, 43 grams in 250 c.c. water.) *To test for cane sugar:* (1) Make a thin section of sugar beet and let it stand a few minutes in a strong solution of copper sulfate. Then carefully rinse off all the salt. (2) Heat in a very strong solution of potassium hydroxide. There will be seen a blue coloration in the section, gradually washing out into the liquid.

To test for oil: Mount a thin section of the endosperm of castor-oil seed in water and examine with high power. Small drops of oil will be quite abundant. Treat the mount with alcanin (henna root in alcohol). The drops of oil will stain red. This is the standard test for fats and oils.

To examine gum-resin: Mount a little of the "milky" juice of the leaf stem of the garden poinsettia (Euphorbia pulcherrima). It is of a creamy consistency. Examination under the microscope shows that it is not white, as it seems to the naked eye. The particles are yellowish or colorless and are insoluble. These particles are gum resin. They have been emulsified by the plant, making the juice appear white.

398. CONTENTS NOT IN SOLUTION.—Starch is the most abundant of the solid products of the cell. Starch grains have a definite form for each group of plants, and groups can be determined by the form of their starch grains. Detection of adulteration of various products containing starch is accomplished by the aid of the microscope. In potato starch the grains are ovate, with a "nucleus" near one end, as shown in Fig. 391. In poinsettia they are dumb-bell-shaped, with two nuclei (Fig. 391). In corn they have equal diameters, with radial fissures. In Egyptian lotus they are forked or branched. So far as known all starch grains are marked with rings, giving a striated appearance, due to the difference in density of the layers. When all water is driven out of the starch the rings disappear. The layers are more or less concentric, and are formed about a starch nucleus.



391. Starch grains. *a*, potato; *b*, poinsettia; *c*, rice.

399. Starch grains may be simple, as found in potato, wheat, arrow-root, corn, and many others; or they may be in groups called **compound grains**, as in oats, rice (Fig. 391), and many of the grasses.

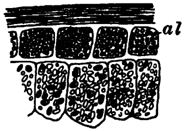
400. Starch may be found **in all parts of the plant.** It is first formed in presence of chlorophyll, mostly in the leaves, and from there it is carried to some other part of the plant, as to the roots or tubers, to be stored or to be used. When found in the presence of chlorophyll it is called **transitory starch,** because it is soon converted into liquid compounds to be transported to other parts of the plant. When deposited for future use, as in twigs and tubers, it is **stored starch.**

401. The **composition of starch** is in the proportion of $C_6H_{10}O_5$. The grains are insoluble in cold water, but by saliva they are changed to sugars, which are soluble. Great heat converts them into dextrine, which is soluble in water.

Starch turns blue with iodine (75). The color may be driven away by heat, but will return again as the temperature lowers. *To test for starch:* Make pastes with wheat flour, potato starch, and corn starch. Treat a little of each with a solution of rather dilute iodine. Try grains from crushed rice with the same solution. Are they the same color? Cut a thin section from a potato, treat with iodine and examine under the microscope. *To study starch grains:* Mount in cold water a few grains of starch from each of the following: potato, wheat, arrow-root (buy at drug store), rice, oats, corn, euphorbia. Study the sizes, forms, layers, fissures, and location of nuclei, and make a drawing of a few grains of each.

402. **Amylo-dextrine** is a solid product of the cell much resembling starch in structure, appearance, and use. With the iodine-test the grains change to a wine-red color. Seeds of rice, sorghum, wild rice, and other plants contain amylo-dextrine. Amylo-dextrine is a half-way stage in the conversion of starch into maltose and dextrine. These latter substances do not react with iodine.

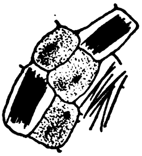
403. Protein or nitrogenous matter occurs largely in the form of **aleurone grains**, and is most abundant in seeds of various kinds. The grains are very small, colorless or yellowish in most plants, rarely red or green. In the common cereals they occupy the outer layer of cells of the endosperm. Fig. 392. In many other cases they are distributed throughout the seed. The grains vary in size and form in different species, but are rather constant within each group. They are entirely soluble in water unless certain hard parts or bodies, known as **inclusions**, are present, and these may remain undissolved. The inclusions may be (*a*) *crystaloids*, as in potato, castor-oil seed; (*b*) *globoids*, as in peach, mustard; (*c*) *calcium oxa-*

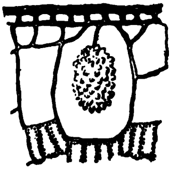


392. Aleurone grains (*al*) in kernel of wheat.

late crystals, as in grape seed. *To study aleurone grains and their inclusions:* Cut a thin cross-section of the peripheral cells of a grain of wheat and mount in alcohol. Stain with an alcoholic solution of iodine to color the grains yellow, and examine with the highest power. Make a sketch of a few layers of cells, just beneath the epidermis. Make a sketch of a few of the grains removed from the cells. While looking at the mount run a little water under the cover glass and watch the result. Make a similar mount and study of the endosperm of castor-oil seed, or of grape seed. In the castor-oil seed look for inclusions of large crystaloids and small globoids. In the grape seed globoids should be found with crystals of calcium oxalate within them. This experiment will require the power of $\frac{1}{6}$- or $\frac{1}{5}$-inch objective.

404. **Cells may contain crystals.** Besides the crystals which are found as inclusions of aleurone grains, many others may be found in many plants. In onion skin they are prisms; in night-shade they are in the form of crystal flour; in the petioles of the peach they are roundish, with many projecting angles; in the rootstock of skunk cabbage and the bulbs of hyacinth they are needle-shaped and are called **raphides** (Fig. 393). In the leaf of the India-rubber plant (common in greenhouses) are found compound clusters resembling bunches of grapes, which are called **cystoliths** (Fig. 394). These are concretions and not true crystals. In saxifrage mineral matter appears as incrustations on the surface of the plant. Towards autumn, crystals of calcium oxalate become very abundant in the leaves of many deciduous trees: **examine cross-sections of peach petiole in June and again**


393. Raphides of rhizome of skunk cabbage.


394. Cystolith in leaf of rubber plant.—Ficus elastica.

in October. *To study crystals and cystoliths:* section the rootstock of skunk cabbage or Jack-in-the-pulpit, the leaf of Ficus elastica, the leaf of ivy (Hedera helix); make a separate mount of each in water, and examine with the high power. When the crystals are found, draw them, with a view of the adjacent cells. Make a similar study of a bit of thin onion skin.

405. **Summary of cell-contents and products:**

1. Chlorophyll.
2. Cell-sap, and substances found in solution.
3. Starch.
4. Amylo-dextrine.
5. Aleurone grains (crystaloids and globoids).
6. True crystals, and other mineral matter.

REVIEW.—Name six classes of contents or products of the cell. Where found? Of what use? What is chlorophyll? What is its use? What is assimilation (170)? Give outline of the products of cells found dissolved in cell-sap. What are the uses of sugar to plants? Name some kinds of sugar found in plants. Describe an experiment to test for glucose. Same for cane sugar. How may we find the oil in plants? Describe an experiment for the study of gum-resin. Why does the juice containing it appear white? Describe starch grains of potato. Tell how starch grains of other plants studied differ from those of potato. What are the uses of starch to the plant? Where is the plant's starch factory? Describe an experiment to test for starch. Name some plants in which we may find amylo-dextrine. How does its test differ from that for starch? What are aleurone grains? In what cells are they found in kernels of wheat? Name some of the forms in which we find true crystals in plant cells.

NOTE TO PARAGRAPH 397.—The digestion of starch is produced by means of *enzyms* or unorganized ferments (i. e., ferments which are not bacterial or fungal, but are chemical substances). These ferments, as diastase, are present in seeds and other living tissues containing starch. During dormant periods the enzyms either are not present, or their action is prohibited by the presence of other substances. There are various specific enzyms, each producing definite chemical changes.

Grape sugar and its associate, fruit sugar, appear to be the forms most generally useful to plants. Cane sugar is readily inverted into these sugars.

CHAPTER XXXIII

TISSUES

406. The lowest plants are **unicellular** or composed of only one cell. Of such are bacteria (Fig. 123). All the higher plants are composed of collections or aggregations of innumerable cells: they are **multicellular.** If we examine the cells of the stem, the leaves, and the roots of any common garden plant we find that they differ very widely from each other in *shape*, *size*, and *texture*.

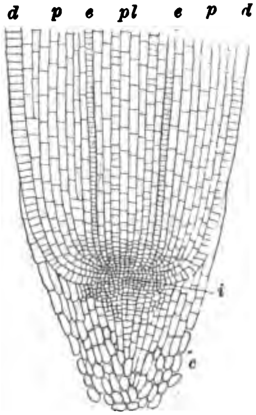
407. Any group of similar cells is called a **tissue.** Each of the different tissues of a plant *has its own type of cells*, although the cells in a tissue may differ from each other in various minor ways.

408. **PARENCHYMATOUS TISSUE.**—Thin-walled cells are known as **parenchyma cells.** When they unite they form **parenchymatous tissue.** These may or may not be elongated in form, and they usually contain protoplasm. Parenchymatous tissue is found at the growing point of a shoot or root (Fig. 395); in the mesophyll (soft pulpy part) of the leaves (Fig. 411); around the vascular bundles of stems and roots (Fig. 402 *f*), and in a few other places, as pith, medullary rays, etc. The cells of this tissue may be *meristematic*—in a state of active division and growth; or they may be *permanent*, no longer able to divide.

409. One important use of this tissue is **to form other tissues**, as in growing points. Near the end of any young root or shoot the cells are found to differ from each other more or less, according to the distance from the point. This differentiation takes place in the region just back of

the growing point. In the mesophyll (or middle soft part) of leaves the elaboration of plant-food takes place. Intercellular spaces filled with air and other gases are common in this tissue of leaves, as well as in parenchyma of other parts of the plant.

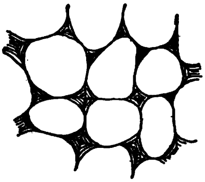
410. To study growing points, use the hypocotyl of Indian corn which has grown about one-half inch. The material should be placed in 40 per cent alcohol for a few hours, then in 70 per cent for the same length of time, and then in 95 per cent until ready for use. Make a series of longitudinal sections, stain with hematoxylin, mount, and then select the middle or median one for study with the high power. Note these points (Fig. 395): (*a*) Root-cap beyond the growing point. (*b*) The shape of the end of the root proper and the shape of the cells found there. (*c*) The group of cells in the middle of the first layers beneath the root-cap. This group is the growing point. (*d*) Study the slight differences in the tissues a short distance back of the growing point. There are four regions: the **plerome,** several rows of cells in the center; the **endodermis,** composed of a single layer on each side; the **periblem,** of several layers outside the endodermis, and the **dermatogen,** on the outer edges. Make a drawing of the section. If a series of the cross-sections of the hypocotyl should be made and studied, beginning near the growing point and running back some distance, it would be found that these four tissues become more distinctly marked. The central cylinder of plerome will contain the



395. Growing point of root of Indian corn. *d*, *d*, dermatogen; *p*, *p*, periblem; *e*, *e*, endodermis; *pl*, plerome; *i*, initial group of cells, or growing point proper; *c*, root-cap.

ducts and vessels; the endodermis remains as endodermis; periblem becomes the cortex of parenchyma; the dermatogen becomes the epidermis of the root.

411. **EPIDERMAL TISSUE.**—This is a special modification of parenchyma, comprising the thin layers on the exterior of leaves and stems. The cells are often tabular or platelike in form, as in the epidermis of leaves (Fig. 115); and their outer surface bears a layer of cuticle, a protective substance which is insoluble even in sulfuric acid. They do not bear chlorophyll and often contain only cell-sap, with a little protoplasm. Their walls are much thickened in some cases, as in Figs. 394 and 414. *Hairs and bristles* are considered to be modified epidermal tissue.



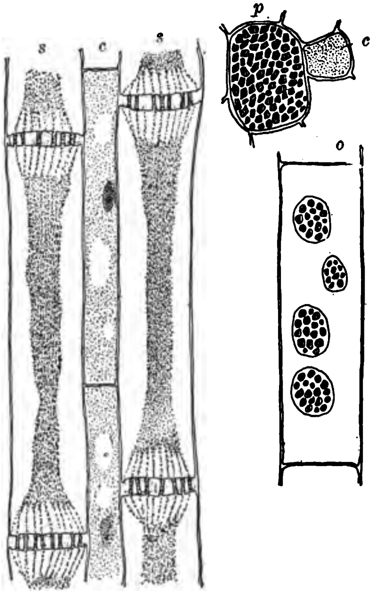
396. Collenchyma in wild jewel-weed or touch-me-not (impatiens).

412. **COLLENCHYMATOUS TISSUE.**—Tissue composed of cells thickened at the angles, not much elongated and not lapping at the ends, is known as **collenchyma** (Fig. 396). It is strengthening tissue. Good examples are found in such vines as pumpkin, cucumber and gourd. The tissue is slightly elastic and allows of some stretching. Cut a few thin cross-sections of large stems of jewel-weed, and mount in water. Study with high power.

413. **SOFT BAST OR SIEVE TISSUE.**—In the higher plants is a tissue known as **soft bast** or **sieve tissue** (this also forms part of the bundle; 424). It is composed of two types of cells which almost always accompany each other. These are **sieve tubes** and **companion cells** (Fig. 397). Both are elongated, thin-walled and blunt at the ends. The sieve tubes are so called because of the sieve-like areas which they bear in various parts. These areas, called **sieve plates,** are commonly at the ends (as partitions) but may be in the lateral walls. Fig. 397. They serve to connect the cell-cavities with each other, and through

them the protosplasm strands extend, as shown in the figure. Their exact function is not known.

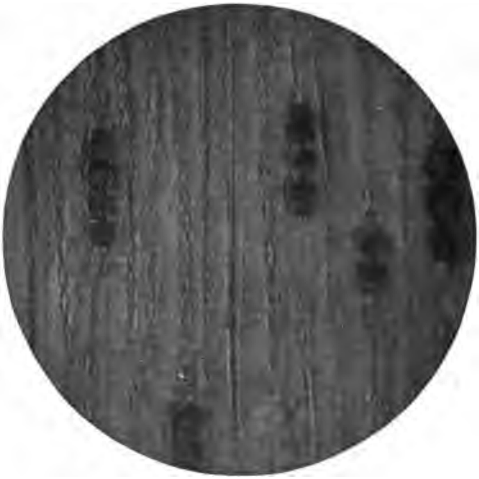
414. **PROSENCHYMATOUS TISSUE.**—Several elongated and strong tissues, which greatly strengthen the stems in which they are found, are collectively known as **prosenchyma.** The cells of these tissues become much thickened by the addition of layers to the inner surface, and finally lose their protoplasm. They may, at times, serve as store-rooms for starch and other nutrients, and take an important part in the transfer of the plant juices. Some writers call this group of tissues sclerenchyma.



397. Bast-tissue. *s*, *s*, sieve tubes; *c*, companion cell; *p*, shows a top view of a sieve plate, with a companion cell, *c*, at the side; *o*, shows sieve plates in the side of the cell. In *s*, *s*, the protoplasm is shrunken from the walls by reagents.

415. There are four main varieties of tissues which may be included under prosenchyma. (1) **Fibrous tissue,** composed of very thick-walled cells with very small central cavities. F, Fig. 401. They are very long and tapering at the ends, which lap. Such tissue is found in many plants where it often wholly or in part surrounds the fibro-vascular bundles. It is more often but not always found near the soft bast: hence the cells are sometimes called *bast fibers* or *hard bast.* (2) **Wood tissue,** or **wood fibers.** This is composed of cells much like the preceding in structure,

but with thinner walls and the central cavity not so nearly closed. In some cases such fibers have transverse walls. Wood cells constitute a large part of the wood of some plants and are in other cases found scattered only among the other prosenchyma. (3) **Tracheids.** Cells of this tissue differ from ordinary cells in being supplied with numerous bordered pits or other characteristic markings.



398. Longitudinal tangential section of Scotch pine wood, highly magnified. It shows tracheids with bordered pits. The dark cells are ends of medullary rays.

They constitute the largest part of the wood of the pines and other gymnosperms. Fig. 398. (4) **Vascular tissue,** composed of large cells which become confluent end to end, forming long tubes or ducts. TT′, Fig. 401. From the thickened markings which these cells bear they are named *spiral*, *annular*, *pitted*, *scalariform*, etc. Fig. 389. These vessels are often of considerable length, but are never continuous through the entire plant. Cut a grape-vine stem 2 or 3 feet long. Place one cut end in a glass of water and with the other end in the mouth, try to force air through the stem. If not successful, shorten the stem a little.

416. **SCLERENCHYMATOUS OR SCLEROTIC TISSUE.**—**Sclerenchyma cells** are hard, not elongated, often somewhat spherical, and their thickened walls are provided with simple or branching canals. The cells of this tissue are illustrated by the common grit cells of the pear and some other fruits. They are also found in the coats of many seeds, in nut shells, in the pith of some plants. Hold a large gritty part of a pear between two pieces of smooth elder pith or cork and make free-hand sections. Mount in water. Make a drawing of a single cell showing thickness of wall, size of central cavity, wall markings. Note the general shape of the cells.

417. **LATICIFEROUS TISSUE.**—That tissue found in many plants which contain a milky liquid is called **laticiferous tissue.** There is no fixed type for the vessels which carry this fluid, as they vary greatly in different plants, being simple in the asclepias (milk weed), and complex in the dandelion.

418. **TISSUE SYSTEMS.**—The parts of complex plants may be conveniently grouped into three *tissue systems:* (1) **Fibro-vascular tissue system.** This is composed of **fibro-vascular bundles.** The fibrous framework of roots, stems, and leaves is made of fibro-vascular bundles. (Fibro-vascular means *fibrous* or long and slender, and having long *openings* or *channels.*) Each bundle is composed of two fundamental parts: *phloem* and *xylem.* The bast fibers may or may not be present. Phloem is another name for the *soft bast* or *sieve tissue*, while xylem is the name of the lignified or woody part and is composed chiefly of the *wood cells*, *tracheids*, and *ducts.* In stems of dicotyledons (exogens), these two parts of the bundle are separated by **cambium**, a meristematic layer giving rise to xylem on one side and to phloem on the other. For types of bundles, see next chapter. (2) **Fundamental tissue system.** This is composed of the parenchyma-

tous tissue already described. The fibro-vascular system may be said to be imbedded in the fundamental tissue. (3) **Epidermal tissue system.** This is the covering of the other systems, and is composed of epidermal tissue, already described. It should be borne in mind that the types of cells and tissues as defined in this chapter are not all that may be found in plants. There are many intermediate forms, e. g., tracheids and ducts blend the one into the other; and the same is true of wood cells and tracheids.

419. **Summary of tissues studied:**

1. Parenchymatous tissue.
    - *a*. meristematic.
    - *b*. permanent.
2. Epidermal tissue.
3. Collenchymatous tissue.
4. Soft bast or phloem (sieve tissue).
5. Prosenchymatous tissue.
    - *a*. Fibrous tissue or bast fibers.
    - *b*. Wood tissue or wood fibers.
    - *c*. Tracheids.
    - *d*. Vascular tissue or ducts.
6. Sclerenchymatous or sclerotic tissue.
7. Laticiferous tissue.
8. Tissue systems.

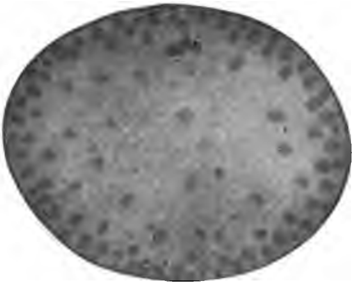
REVIEW.—What is a tissue? How may two tissues differ? What is parenchymatous tissue? Name three places where this is found. Distinguish between meristematic and permanent tissue. Name two uses of parenchymatous tissue. Of what use are the intercellular spaces of leaves? Describe the parts studied in the section of root tip. What part of this tip will become vascular? Describe epidermal tissue. Collenchyma. Sieve tissue. Of what use are the sieve areas? What are the chief uses of prosenchyma? Describe fibrous tissue, wood cells or wood fibers; tracheids; ducts. What does your experiment in blowing air through a grapevine stem indicate? Describe cells of sclerotic tissue. Laticiferous tissue. Name three tissue systems. What are fibro-vascular bundles? What two classes of tissue are found in each bundle? Of what is phloem composed? Xylem.

CHAPTER XXXIV

STRUCTURE OF STEMS AND ROOTS

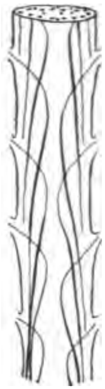
420. There are two main types of stem structure found among flowering plants, which have their differences based upon the arrangement of the fibro-vascular bundles. These types are *endogenous* and *exogenous*.

421. **ENDOGENOUS STEMS.**—Plants with this form of stem are the *monocotyledons*. The vascular bundles are *irregularly scattered through the fundamental tissue* of the stem (Fig. 399), and are not arranged in circles about a common center. The bundles are *not parallel with each other* and are not of the same size throughout their length. Fig. 400 shows the direction often taken by the bundles in the stem. On the exterior there is either an **epidermis** or a **false rind.** The only trees which have this kind of stem are natives of the tropics or of warm countries. The palm is one of them, and these stems are sometimes called the palm type. In our own climate we find many examples, such as greenbrier, Indian corn, asparagus, grasses, orchids, iris, and cat-tail. *To study arrangement of bundles in corn:* Cut thin sections of a small corn stem which has been preserved in alcohol. Stain with hematoxylin. Examine with the low power, and make a sketch showing the



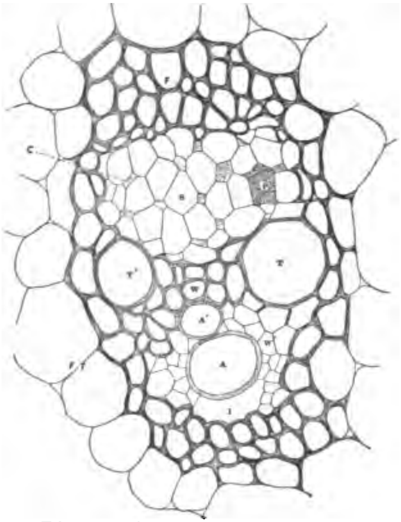
399. Cross-section of corn-stalk, showing the scattered fibro-vascular bundles. Slightly enlarged.

arrangement of the bundles. The sections, if mounted in a permanent way, as in balsam, may be kept for further study of the bundles. Compare with Fig. 401.



400. Diagram to show the course of fibro-vascular bundles in monocotyledons.

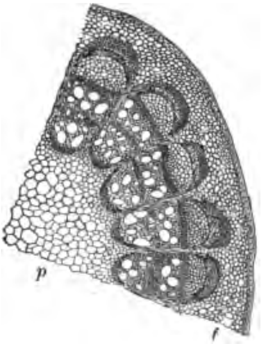
422. **EXOGENOUS STEMS.**—The fibro-vascular bundles in exogenous (or dicotyledonous) stems are arranged *in a circle around the center*, which is usually filled with pith. Outside the ring of bundles is a **cortex** of fundamental tissue. Around this is either a *layer of cork* or an **epidermis.** Layers of parenchyma cells, called **medullary rays,** are found between the bundles and often extending from the central pith to the outer cortex. These usually are prominent in young stems of woody plants and in vines. Fig. 404. All trees and nearly all other woody plants of the temperate regions, as well as many herbaceous plants, show this plan of stem. The medullary rays are very prominent in oak wood. These rays are lignified in the xylem part of the bundle and non-lignified in the phloem part. *To study arrangement of bundles in exogens:* Prepare thin cross-sections of the stems of menispermum (moonseed),



401. Fibro-vascular bundles of Indian corn, much magnified. A, annular vessel; A', annular or spiral vessel; TT', thick-walled vessels; W, tracheids or woody tissue; F, sheath of fibrous tissue surrounding the bundle; FT, fundamental tissue or pith; S, sieve tissue; P, sieve plate; C, companion cell; I, intercellular space, formed by tearing down of adjacent cells; W', wood parenchyma.

one year old. Stain with hematoxylin. Make a permanent mount. Study with low power, and make a sketch showing the shape and location of the fibro-vascular bundles. Fig. 402. Save the mount for further study. If menispermum stems are not easily obtained, ivy (Hedera helix) or clematis may be substituted.

423. **OTHER STEMS.**—Besides the two types of stems studied above, which are prevalent among phenogams, there are other structures of stems found among the cryptogams. A common arrangement of the bundles is in the form of a circle some distance from the center, with a few other bundles within the circle. Within the circle also are sometimes found large areas of fibrous tissue. Fig. 403. There are, however, wide variations from this arrangement, but this mode of arrangement is often called the *fern type* of stem.

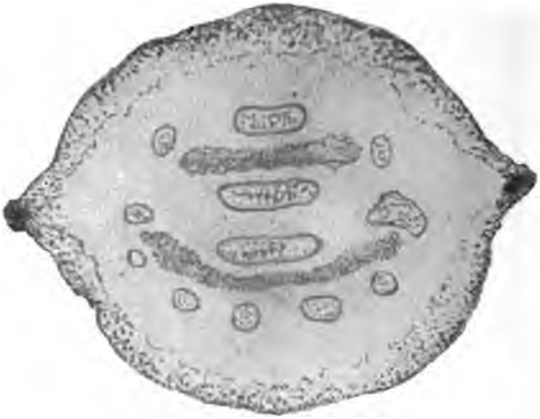


402. Arrangement of tissues in 2-year-old stem of moonseed. *p*, pith ; *f*, fundamental tissue ; *e*, epidermis. The fibro-vascular bundles are very prominent.

424. **THREE TYPES OF BUNDLES.**—It has already been said (418) that every fibro-vascular bundle is made up of two parts: (1) *phloem* or *soft bast;* (2) *xylem* or *wood.* The relative position of these two strands of tissue is very important. There are three plans of arrangement, on which three types of bundles are based. These plans are **collateral, concentric,** and **radial.**

425. In collateral bundles, the phloem and xylem are placed **side by side,** the xylem being nearer the center of the stem and the phloem outside or nearer the circumference of the stem. We find this plan in the stems of phenogams. The collateral bundles may be either **open** or **closed.** Open bundles are those which continue to increase

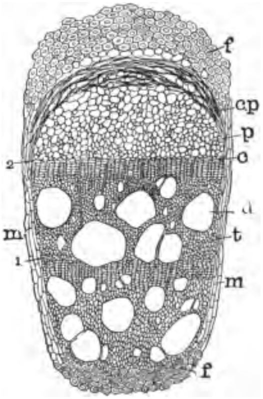
in size during life by the presence of a growing layer at the line of union of the phloem and xylem. This layer of growing cells is called **cambium.** Dicotyledonous stems have open collateral bundles. Fig. 402. Closed bundles are those which cease growing very early and have no cambium or growing layer. They are called closed, perhaps from the fact that there is no means by which they may become larger. Stems of monocotyledons have bundles of the closed collateral type. Examine with high power cross-sections of menispermum stems and corn stems (see Figs. 401, 402, 404), which have been stained with hematoxylin. Study the tissues found in a single bundle of each, with the aid of the illustrations.



403. Cross-section of root of brake (Pteris aquilina), showing 12 concentric fibro-vascular bundles. The two long dark strands are composed of fibrous tissue.

426. In concentric bundles, the **xylem is centrally placed in the bundle and the phloem is all around it,** as in club mosses and ferns (Fig. 403); or the **phloem is in the center of the bundle and the xylem surrounds it,** as in the underground stems of some monocotyledons, as asparagus. Figs. 405, 406. *To see concentric bundles:*

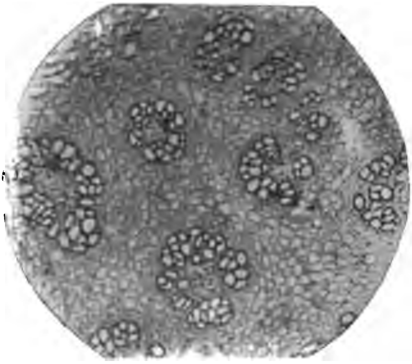
Prepare cross-sections of the stem of pteris or aspidium. They should be cut very thin and stained with hematoxylin. Make a sketch showing the arrangement of bundles. Then with the highest power study a single bundle and the sheath surrounding it. Draw.



404. Cross-section of fibro-vascular bundle of moonseed (see Fig. 402). *f, f*, crescent-shaped sheaths of bast fibre; *p*, phloem; *cp*, crushed phloem; *c*, cambium; *d*, xylem ducts; *t*, xylem tracheids; *m*, medullary rays of fundamental tissue; from *c* to *f* (at bottom), xylem; *1*, end of first year's growth; *2*, end of second year's growth of wood.

427. Radial bundles are characterized by having **several strands of xylem tissue radiating from near the center,** and each strand is separated from the next by a mass of phloem. This plan is typical of young roots and rootlets, in which there is but one bundle.

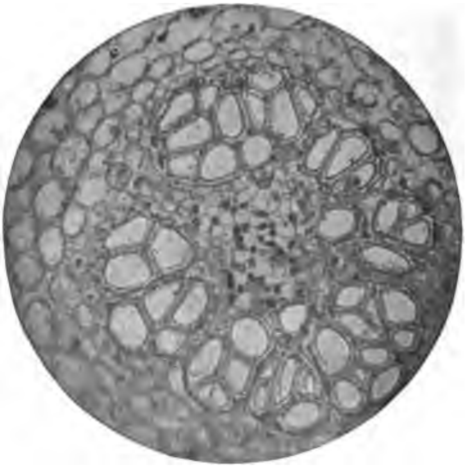
428. **SECONDARY THICKENING OF STEMS.** — Dicotyledonous (or exogenous) stems with open collateral bundles may **increase in diameter each year.** If they are perennial they may **add a ring of growth** each spring (Fig. 407). These rings may be counted on the smooth cross-cut surface of a tree, and the exact age of the tree usually can be very closely determined. All growth in thickness due to the formation of new cells outside of the primary wood is called **secondary thickening.**



405. Part of cross-section of root-stock of asparagus, showing a few fibro-vascular bundles.

429. As we have

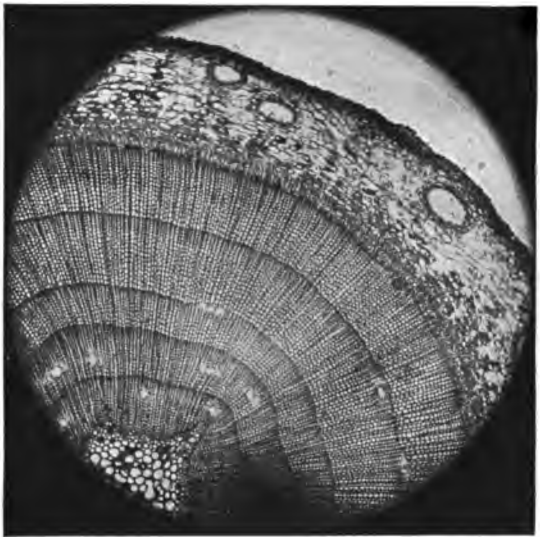
seen (425), there is a **cambium** or growing layer in every open collateral bundle just between the xylem and phloem. Each spring the cells of this layer divide many times and *form new cells both inside and outside the cambium ring.* Those formed inside become thick walled and are xylem. Those formed to the outside of the ring are gradually changed into phloem. The crowding of the cells within the cambium ring causes the ring itself to enlarge its circumference and move outward by this growth. *To study secondary thickening:* Cut thin cross-sections of basswood stems of different ages (one to three years old). Stain and mount. Examine with low power and sketch the arrangement of bundles in the oldest and youngest. Note the effect of growth on the medullary rays. Test them with iodine for starch. Now with the high power study the peculiar character of the bast tissue. Note the abundance of fibrous tissue found all through it. Draw a single bundle from the stem one year old, carefully



406. Enlargement of a single concentric bundle from Fig. 405.

showing the location of the cambium and the different tissues found in the xylem and phloem strands (Fig. 408). It may be thought best to precede this experiment with a similar study of two-year-old stem of moonseed, ivy or other vines.

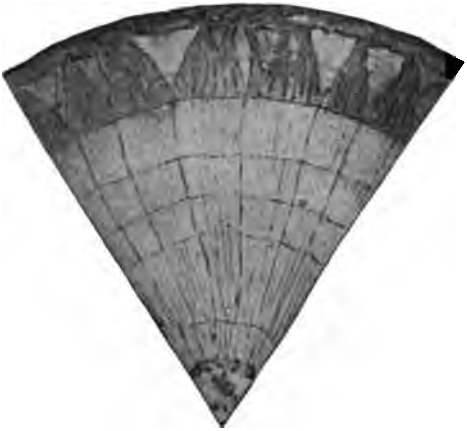
430. **BARK.**—In most woody plants that part of the stem which is outside the cambium ring is called **bark.**



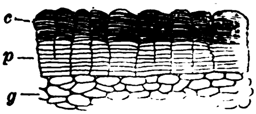
407. White pine stem 5 years old. The outermost layer is bark.

At first it contains the epidermis or outer layer of cells, the phloem and the cortex lying between the epidermis and the phloem. The gradual growth of the stem causes the outer dead layers of bark to crack more or less irregularly and finally to split off. Examples of this can be seen on the trunks of any large trees. Before the tree is many years old the cortical cells of the bark become much crushed and are lost to view. The epidermis is shed rather early in the life of the tree.

431. Usually very early in the life of the stem a *corky* layer of bark is produced. This is the product of an active layer of cells called **phellogen.** This layer is first found at those places where the stomates or breathing pores were located. The epidermis is first crowded off at these places, and the rough corky spots are called **lenticels.** Phellogen is very active in the cork oak of Spain, but we find it in nearly all woody plants. In such plants as buttonwood (sycamore), in which the bark peels off in thin, flat layers, the phellogen layer is nearly uniformly active in all parts, while in many other cases there is very little uniformity. In wahoo (burning bush) it is in four bands, giving rise to four corner wings. In the section of menispermum already studied, it is found only under the lenticel spots where the stomates have been located. Fig. 409 shows structure of the outer bark as found in the whole circumference of the three-year-old stem of red currant. *To study phellogen and corky tissue:* Cut thin cross-sections of red currant from stems two or three years old which have been kept in alcohol at least several hours. The sections should be stained. With the highest power make a careful study of



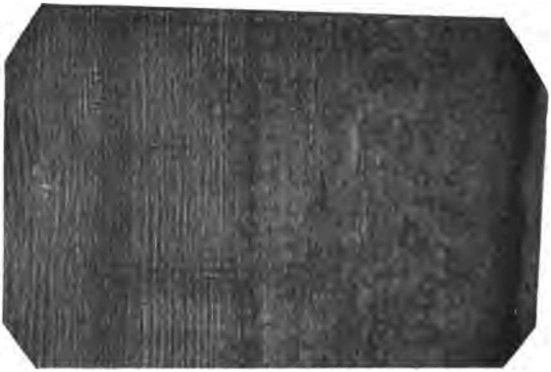
408. Section of basswood stem, 5 years old. The cone-shaped growths of phloem are plainly seen.



409. Cross-section of red currant twig, showing bark. c, corky tissue; p, phellogen; g, parenchyma or cortex.

the phellogen and the corky tissue outside of it. Draw. The relation of bark to woody tissue in pine is shown in Fig. 410. Cork tissue may be studied to advantage in the skin of the potato.

432. **STRUCTURE OF ROOTS.**—At the growing point the root has a **cap** (of small compact cells) which protects the delicate tissues from injury (Fig. 395). Such a protection is not found in growing points (buds) of stems. In their internal structure *roots differ from stems*, especially when very young. Young roots have the **radial type** of bundles, and there is then usually only one bundle in the root. The number of strands of xylem radiating from the center differs with the plant. In roots also there is almost uniformly present a true endodermis. This layer is found just within the cortex and is composed of rather thick-walled cells. However, many rhizomes and stems have a true endodermis. *To study corn roots:* From the roots of Indian corn a few weeks old cut thin cross-sections; stain and mount. With the aid of the low power make a sketch showing the

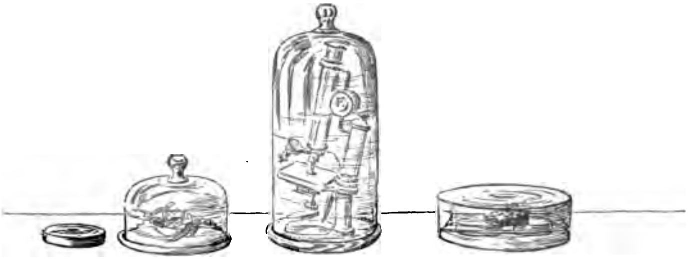


410. White pine stem in radial longitudinal section. Tracheids on the left with medullary rays crossing them. Next to the wood is the phloem, then fundamental tissue, then the dark bark.

arrangement of the strands of wood and bast, and also the amount of fundamental tissue. Use the highest power and draw a portion including one strand of wood and two of bast. In this portion draw the tissues from the center out beyond the endodermis. Sections may also be made of the roots of germinating pumpkins or squashes.

REVIEW.—Name two types of stems found among flowering plants. Describe each and give examples to illustrate them. Give the plan of arrangement of bundles in fern stems. How many types of bundles are there? Upon what do their differences depend? Describe and give examples of collateral bundles. What difference is there between open and closed collateral bundles? Give examples of each. Describe and give examples of concentric bundles. Radial bundles. What is secondary thickening? What plants show it? What is the layer called which forms the new cells in a bundle? When is this layer most active? Describe the work of this layer. What part of each bundle of a dicotyledon is found in the bark? What are lenticels? What is phellogen? Describe the work of phellogen in any plant you have studied. Where is the root cap? What is its use? Describe fully the structure of roots, telling how they differ from stems.

NOTE TO PARAGRAPH 422.—In woody stems the compression is such that the student is usually puzzled to understand the bundle structure. The subject will be simplified if he compares (on cross-section), the bundles in such a plant as the cucumber with that part of the vascular ring which lies between any two medullary rays in one-year old stems of peach, elm, oak, etc.



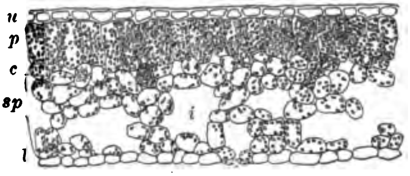
All material and apparatus should be kept under cover when not in use.

CHAPTER XXXV

STRUCTURE OF LEAVES

433. Besides the **framework** or system of veins found in blades of all leaves, there is a soft tissue (408) called **mesophyll** or **leaf-parenchyma,** and an **epidermis** which covers the entire outside part.

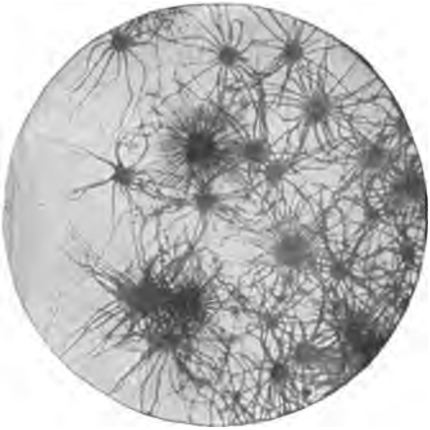
434. **MESOPHYLL.**— The mesophyll **is not all alike** or **homogeneous.** The upper layer of it is composed of elongated cells placed perpendicular to the surface of the leaf. These are called **palisade cells.** The *chlorophyll grains are most abundant in them*, because they are on the side of the leaf most directly exposed to the sunlight. Below the palisade cells is the **spongy parenchyma** composed of cells more or less spherical in shape, irregularly arranged, and provided with many intercellular air cavities. Fig. 411; also Fig. 115. In leaves of some plants exposed to strong light there may be more than one layer of palisade cells, as in the India-rubber plant and oleander. Ivy when grown in bright light will develop two such layers of cells, but in shaded places it may be found as in Fig. 411. Such plants as iris and compass plant, which have both surfaces of the leaf equally exposed to sunlight, usually have a palisade layer beneath each epidermis.



411. Cross-section of ivy leaf, which grew in shade and has only one layer of palisade cells. *u*, upper epidermis; *p*, palisade cells; *c*, a crystal; *sp*, spongy parenchyma; *i*, intercellular space; *l*, lower epidermis. The plant here intended is the true or English ivy, Hedera helix.

435. **EPIDERMIS.**—The outer or epidermal cells of leaves do not bear chlorophyll, but are usually so transparent that the green mesophyll can be seen through them. They often become very thick-walled, and are in most plants devoid of all protoplasm except a thin layer lining the walls, the cavities being filled with cell-sap. This sap is sometimes colored, as in the under surface of begonia leaves. It is not common to find more than one layer of epidermal cells on each surface of a leaf. The epidermis serves to retain moisture in the leaf. In desert plants the epidermis as a rule is very thick and has a dense cuticle.

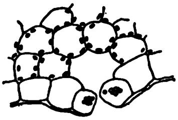
436. There are various **outgrowths of the epidermis.** Hairs are the chief of these. They may be (1) **simple,** as on primula, geranium, nægelia; (2) **once branched,** as on wallflower; (3) **compound,** as on verbascum or mullein; (4) **disk-like,** as on shepherdia (Fig. 412); (5) **stellate,** or star-shaped, as in certain crucifers. In some cases the hairs are **glandular,** as in Primula Sinensis and certain hairs of pumpkin flowers. *To study epidermal hairs:* For this study use the leaves of the plants mentioned above or others which may be substituted. Cross-sections may be made so as to bring hairs on the edge of the sections. Or in some cases the hairs may be peeled or scraped from the epidermis and placed



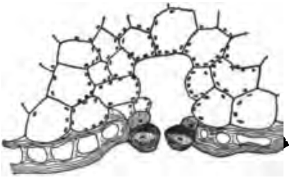
412. Disk-like or radial hairs of shepherdia.

in water on a slide. Make sketches of the different kinds of hairs.

437. **STOMATES.**— **Stomates** or **breathing-pores** are **small openings** or pores in the epidermis of leaves and soft stems to allow the passage of air and other gases and vapors. They are **placed near the large intercellular spaces** of the mesophyll. Fig. 413 shows the usual structure. There are two **guard cells** at the mouth of each stomate, which may in most cases open or close the passage as the conditions of the atmosphere may require. In Fig. 414 is shown a case in which there are compound guard cells, that of ivy. On the margins of certain leaves, as of fuchsia, impatiens, cabbage, are modified stomates known as *water-pores*.



413. Stomate of geranium leaf, showing the guard cells.



414. Stomate of ivy, showing compound guard cells.

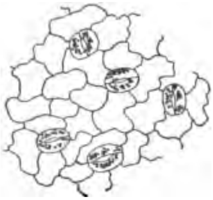
438. Stomates are **very numerous**, as will be seen from the numbers giving the pores to each square inch of leaf surface:

	Lower surface.	Upper surface.
Peony	13,790	None
Holly	63,600	"
Lilac	160,000	"
Mistletoe	200	200
Tradescantia	2,000	2,000
Garden Flag	11,572	11,572

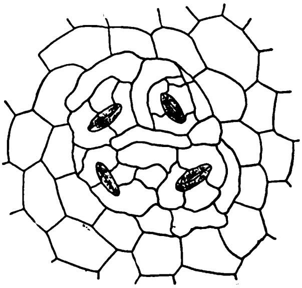
The arrangement of stomates on the leaf **differs with each kind of plant.** Figs. 415 and 416 show stomates on two plants, and also the outlines of contiguous epidermal cells. The guard cells contain chlorophyll.

439. **FALL OF THE LEAF.**—In most common deciduous plants, when the season's work for the leaf is ended, the nutritious matter is withdrawn into the stem, and a layer

of corky cells is completed over the surface of the stem where the leaf is attached. The leaf soon falls. It often falls even before killed by frost. Deciduous leaves begin to show the surface line of articulation in the early growing season. This articulation may be observed at any time during the summer. The area of the twig once covered by the petioles is called the **leaf-scar** after the leaf has fallen. Figs. 53, 83, 86 show a number of leaf-scars.



415. Stomates of geranium leaf.

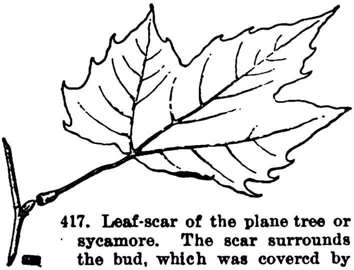


416. Grouped stomates on a begonia leaf.

Fig. 417 shows the leaf-scar in the form of a ring surrounding the bud, for in the plane tree the bud is covered by the hollowed end of the petiole; sumac is a similar case. Examine with a hand-lens leaf-scars of several woody plants. Note the number of bundle-scars in each leaf-scar. Sections may be cut through a leaf-scar and examined with the microscope. Note the character of cells which cover the leaf-scar surface. Compare 204.

REVIEW.—Name three tissues found in leaves. On the board draw a sketch showing the structure of a leaf as seen in cross-section. What cells of leaves bear protoplasm and chlorophyll? Why do some leaves have palisade cells near both surfaces? Describe epidermal cells. Why are their walls much more thickened in some plants than others? What is the purpose of epidermis? What are stomates? Draw on the board a section through a stomate showing epidermis and mesophyll. What is the work of guard cells? Give some idea of number of stomates in various plants. Name five types of epidermal hairs. What use could be suggested for the dense coat of hairs on leaves of shepherdia? Fig. 412.

NOTE.—*To study leaf tissues:* A number of leaves can be compared by making free-hand cross-sections of leaves held between two pieces of pith or cork, and mounting the material in water. Study such leaves as ivy (Hedera helix), begonia, cycas, geranium, and corn. Note the number of layers of palisade cells, the spongy parenchyma, the epidermal layers. Which cells bear chlorophyll? Write a brief description of the tissues of each leaf and make a drawing of the geranium.



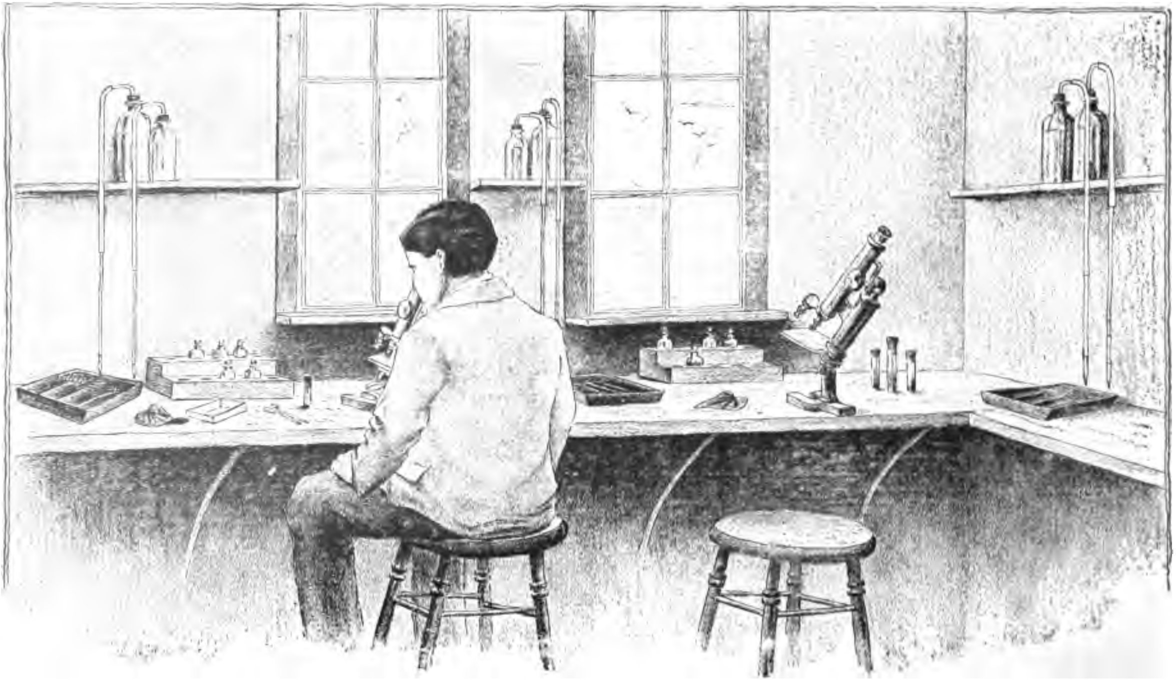
417. Leaf-scar of the plane tree or sycamore. The scar surrounds the bud, which was covered by the hollow base of the petiole.

To study stomates in cross-section: In the cross-sections of leaves of geranium, corn, ivy, lily, or spider-lily prepared for the above experiment, look for the stomates and make a careful drawing from the one you can see best.

Study of stomates in surface view: From the under surface of leaves of geranium and impatiens peel bits of epidermis by tearing the leaf. Mount these in water and examine under low power. Are the stomates scattered or in groups? With aid of a higher power draw a few stomates showing their guard cells and the surrounding epidermal cells. Make a similar study and sketch of the epidermis torn from the under surface of a *Begonia sanguinea* leaf.

Breathing-pores are known as *stomata*, singular *stoma;* also as *stomates*, singular *stomate*.

Looking for light.



A simple laboratory table arranged near the windows of a school room.

Each shelf between the windows holds two bottles, one for water and one for alcohol. These are provided with flexible siphon tubes terminating in a pipette-like point, and closed by a pinch-cock. The siphons hang over a metal tray having bars across the top, on which slides may be placed while staining. A stand contains the necessary reagents. Each set of apparatus can be used by two pupils during each session. It is advisable to support the table by braces running to the wall, in order to escape the vibration of the floor.

PART IV

THE KINDS OF PLANTS

NUMBER OF PLANTS.—Above 125,000 distinct kinds or species of seed-bearing plants are known and described. Probably little more than one-half of the total number now existing on the earth are known. Even in the older countries and regions, seed-bearing plants heretofore unknown to science are discovered now and then. Outlying regions are relatively little known botanically. The larger part of Africa, South America, Central America, China, Central Asia, and the tropical islands are only imperfectly explored for plants. Cryptogamous plants are far more numerous in kinds than seed-plants, and many kinds—as, for example, various bacteria—are almost infinite in numbers of individuals. In the lower ranges of cryptogamous plants, as in fungi and bacteria, many new kinds are constantly being described even in countries in which they have been most carefully studied.

SPECIES.—Each kind of plant is called a species. There is no absolute mark or characteristic of a species. Between many kinds there are intermediate forms, and some kinds vary immensely under different conditions. What one botanist considers as a distinct species, another botanist may regard as only a variety or form of another species. No two botanists agree as to the number of species in any region. Species are not things in themselves. In practice, any kind of plant which is distinct enough to be recognized by a description, and which is fairly constant over a considerable territory, is called a species. We make species merely to enable us to talk and to write about plants: we must have names to call them by. The different kinds of plants are the results of evolution. Probably none of them were created in the beginning as we now find them.

NAMES OF SPECIES.—For one hundred and fifty years (since Linnæus published his "Species Plantarum" in 1753), species have been known by two names, the generic and the specific. The generic name is the name of the genus or group to which the plant belongs: it corresponds to a surname. The specific name belongs only to the particular species or kind: it corresponds to a given or Christian name. Both names are necessary, however, to designate the species. Thus *Quercus* is the generic name of all the oaks. *Quercus alba* is one of the oaks (the white oak), *Q. virens* (the live oak) another. All maples belong to the genus *Acer*, and all elders to *Sambucus*. The same specific name may be used in any genus, as the same Christian name may be used in any family. Thus, there is a *Quercus nigra*, *Sambucus nigra*, *Acer nigrum*, "niger" meaning black.

By common consent, the oldest proper name of any species must stand. If a species happens to have been named and described twice, for example, the first name, if in the proper genus, must hold; the later name becomes a synonym. It sometimes happens that the same specific name has been given to different plants of the same genus. Of course this name can be allowed to stand for only one species, and the other species must receive another name. In order to avoid confusion of this and other kinds, it is customary to write the author's name with the species-name which he makes. Thus, if Gray describes a new Anemone, his name is written after the plant name: *Anemone cylindrica*, Gray. The author's name thus becomes an index to the history of the species-name.

Plant-names are thrown into the forms of the Latin language. When plants first were studied seriously, knowledge was preserved in Latin, and Latin names were used for plants. The Latin form is now a part of the technical system of plant and animal nomenclature, and is accepted in all countries; and the Latin language is as good as any other. As in the Latin language, all plant-names have gender, and the termination of the word is usually different in each gender. The species-name must agree with the genus-name in gender. *Acer* is neuter: so is *A. rubrum* and *A. nigrum*. *Quercus* and *Sambucus* are feminine: so are *Q. nigra* and *S. nigra*. Masculine, feminine, and neuter endings are seen in *Rubus sativus*, *Pastinaca sativa*, *Pisum sativum*. "Sativus" means *cultivated*.

The name of a species not only identifies the species, but classifies it. Thus, if a plant is named in the genus *Acer*, it belongs to the maples; if it is named in *Fragaria*, it belongs to the strawberries; if it is named in *Pyrus*, it is allied to apples and pears; if it is *Helianthus*, it is one of the sunflowers.

USE OF KNOWING PLANT-NAMES.—The name is an introduction to the plant, as it is to a person. It is an index to its history and literature. It enables us to think and to speak about the plant with directness and precision. It brings us nearer to the plant and increases our interest in it.

The name is a means, not an end. Merely to know the name is of little use or satisfaction. Knowing the name should be only one step in knowing the plant. Of late years, the determining of the names of plants has been discouraged as a school-exercise. This is because all inquiry stopped when the name was secured. A name was a stone wall when it should have been a gate.

HOW TO FIND OUT THE NAMES OF PLANTS.—There can be no short-cut to the names of plants, for names cannot be known accurately until the plant is known. The name and the plant should be indissolubly associated in the mind. Study first the plant. If one does not know the plant there is no occasion for knowing its name.

Learn first to classify plants: names will follow. Look for resemblances, and group the plants around some well-known kind. Look for sunflower-like, lily-like, rose-like, mint-like, mustard-like, pea-like, carrot-like plants. These great groups are families. The families of plants are better recognized by studying a few representative plants than by memorizing technical descriptions. Go to the botany and use the keys in these families, in order to run the plant down to its genus and species. If the family is not recognized, use the key to find the family. Use the keys at first: gradually discard them. When one looks for relationships, the vegetable kingdom comes to have continuity and meaning. Merely to know names of plants here and there is of little use.

It is unwise for the beginner to try first to find the name of any plant. Let him first examine familiar plants or those which seem to be related to other plants which he knows. Let him get in mind the bold characteristics of the families which are most dominant in his locality. Names are secondary and incidental. After a time, in case of each new plant, he should be able to give a shrewd guess as to its family; then he may go to the book to verify the guess.

In the following flora, twenty-five well-marked families are chosen for study. Some of them are not the most characteristic of the American vegetation, but they are such as afford easily accessible species, either in the wild or in cultivation, and which are not too difficult for the beginner. *The pupil should begin with plants of which he knows the common names or with which he is familiar.* Several plants should be studied in each family, in order to enable him to grasp the characteristics of the family and thereby to lead him to compare plant-groups and to clarify his perception and widen his horizon. When these families, or the larger part of them, are understood, if the pupil desire further knowledge of species, he may go to the regular manuals in which species are grouped or classified according to their natural affinities. It is well to study more than one plant in a genus whenever possible, for then close comparisons can be made.

MAKING A COLLECTION.—The making of a collection of plants focuses one's attention, defines one's ideas, and affords material for study at any season. The collecting and preserving of plants should be encouraged. Not until one searches for himself, and collects with his own hands, can he know plants. The collection should not be an end, however. It should be only a means of knowing plants as they live and grow. Too often the pupil thinks it sufficient merely to have made a collection, but the collection of itself is scarcely worth the while.

Plants are preserved by drying them under pressure. The collection, when properly arranged and labelled, is an herbarium. Each species should be represented by sufficient specimens to display the stems, foliage, flowers, fruits. If the plant is an herb, its root should be shown. There should be several or many specimens of each species to show the different forms which it assumes. It is less important to have an herbarium of many species than to have one showing the life-phases of a few species. First make specimens of the common species: later one may include the rare ones if he choose, although an herbarium which selects plants merely because they are rare is of little account except as a collection of curiosities. The commonest plants are usually the least represented in herbaria.

Dry the plants between blotters which are 12 inches wide and 18 inches long. These blotters are called "driers." They may be purchased of dealers in botanical supplies, or they can be cut from felt "carpet paper." It is well to place the specimen in a folded sheet of newspaper, and then lay the newspaper between the driers. If the specimens are large or succulent, three or four driers should be laid between them. The sheets may be piled one above another, until the pile becomes so high (12-18 in.) that it tends to tip over. On the top place a board of the dimensions of the drier, and apply twenty to thirty pounds of stones or other weight. Change the driers —but not the newspapers—once a day at first, laying the driers in the sun for a time. In a dry, warm place, most plants will dry in a week or ten days. When thoroughly dried, they retain no soft, sappy, fresh-green areas, and they usually break if bent sharply. They will be perfectly flat.

The specimen may now be secured to strong white paper, known as "mounting paper." The regulation size of the sheets is 11½ x 16¼ inches. It is the quality of heaviest ledger paper. By the ream, it can be bought for one cent or less a sheet. The specimen should be large enough nearly or quite to cover the sheet, unless the entire plant is smaller than this. It may be glued down tight, as one pastes pictures in a scrap-book, or it may be held in place by strips of gummed paper. The former is the better way, because the plants are not so easily broken. Only one species should go on a sheet. In one corner, glue the label. This label should give the place and date of collecting, name of collector, and any information as to height, color, nature of soil, and the like. Sooner or later, the label should contain the name of the plant; but the name need not be determined until after the plant is mounted.

The sheets of one genus are laid together in a folded sheet of strong straw-colored paper. This folded sheet is the "genus cover." Its size when folded is $11\frac{3}{4} \times 16\frac{1}{2}$ inches. On the lower left-hand corner the name of the genus is written. If one has many sheets in one genus —say more than 20—it may be necessary to have more than one cover for them. The covers are laid in cupboards flatwise, one on the other, and the sheets then retain their shape and are always ready for use.

EXPLANATION OF THE FLORA.— The following flora contains 300 species of plants in 139 genera and 25 families. These species are selected from common and representative plants, in the hope that 50 to 100 of them may be secured by any pupil. The pupil should collect his own specimens as far as possible, and he should press and preserve them after he has studied the structure. Familiarity with 100 plants will give the pupil a good grasp of plant forms, provided he does not stop with merely acquiring the names and pressing the specimens. He should know how the plants look, where they grow, how they associate with other plants, how long they live, and the like.

Avoid the use of keys as much as possible: learn to see the plant as a whole: go directly to the family, if possible. But it may be necessary to use keys at first. In this book coördinate parts of the key are marked by the same letter: e.g., F, FF, FFF, are three coördinate entries. Coördinate entries are also introduced by the same catch-word, as "flowers," "leaves," "fruit." Using a key is a process of elimination. First try the plant in A; if it does not belong there, go to AA. Then repeat the search in B, BB, etc., until the family is found.

Synonyms are placed in parenthesis immediately following the accepted name. Thus "**Impatiens biflora,** Walt. (*I. fulva,* Nutt.)" means that the accepted name is Walter's I. biflora, but that the plant is also known by Nuttall's name, I. fulva.

Proper pronunciation is suggested by the accent, which indicates both the emphatic syllable and the length of the vowel. The grave accent (`) indicates a long vowel; the acute (´), a short vowel. Terminal vowels are pronounced in Latin words. The word officinàle is pronounced *officin-ày-ly;* aùrea with *au* as in *Laura;* Virginiàna with the *a* as in *hay;* álba, with *a* as in *had;* acutíloba with *i* as in *hill;* mìnor with *i* as in *mine;* halimifòlia with *o* as in *hole;* Japónica with *o* as in *con;* rùmex with *u* as in *tune;* fúnkia with *u* as in *run*.

Key to the twenty-five families as represented in the following pages

A. CRYPTOGAMS: no flowers or seeds: propagating by means of spores..I. *Fílices*, p. 284

AA. PHENOGAMS: bearing flowers and seeds.

  B. GYMNOSPERMS: seeds naked (not in ovaries), borne in cones or berries: no conspicuous flowers: lvs. needle-shaped or scale-like: plants usually evergreen.......II. *Coniferæ*, p. 286

  BB. ANGIOSPERMS: seeds borne in ovaries: flowers usually showy: lvs. very various, mostly deciduous.

    C. *Monocotyledons:* cotyledon one: lvs. mostly parallel-veined, not falling with a distinct articulation: stem with scattered fibro-vascular bundles (endogenous) and no separable bark: fls. mostly 3-merous.

      D. Flowers small and inconspicuous, borne on a spadix attended by a corrolla-like spathe......III. *Araceæ*, p. 289

      DD. Flowers large and showy, not on spadices.

        E. Stamens 6, or rarely 4.

          F. Ovary free, or superior................IV. *Liliaceæ*, p. 290

          FF. Ovary inferior..................V. *Amaryllidaceæ*, p. 295

        EE. Stamens 3............................VI. *Iridaceæ*, p. 296

    CC. *Dicotyledons:* cotyledons 2 or more: lvs. mostly netted-veined, usually falling with a distinct joint or articulation: stem with concentric layers of wood when more than one year old (exogenous), and a distinct separable bark: fls. mostly 5-merous or 4-merous.

      D. Choripetalæ: petals distinct or wanting (i. e., flowers polypetalous, apetalous, or naked).

        E. Flowers characteristically apetalous or even naked, mostly small and often greenish (*Apetalæ*).

          F. Blossoms monœcious or diœcious, staminate and sometimes pistillate in slender catkins: fruit a 1-seeded nut: trees or shrubs..VII. *Cupuliferæ*, p. 298

FF. Blossoms perfect and not in catkins, or sometimes imperfect and in short catkins, but the fruit not a nut: trees, shrubs, or herbs............. VIII. *Urticaceæ*, p. 301

FFF. Blossoms perfect, not in catkins: fruit an akene: herbs........................ IX. *Polygonaceæ*, p. 304

EE. Flowers characteristically polypetalous, mostly larger and often showy (*Polypetalæ*). Some of the Ranunculaceæ here described are apetalous, but there is a calyx-like involucre underneath the flower.

F. Petals and stamens borne on the not-enlarged torus (hypogynous): ovary superior.

G. Leaves opposite at swollen nodes, very narrow, often grass-like ....X. *Caryophyllaceæ*, p. 306

GG. Leaves alternate or opposite, mostly broad, not grass-like, the nodes usually not conspicuously swollen.

H. Carpels solitary or distinct (i. e., ovary simple) ....XI. *Ranunculaceæ*, p. 308

HH. Carpels variously united (ovary compound).

I. Stamens 6: fruit a silique or silicle......... XII. *Cruciferæ*, p. 310

II. Stamens numerous: fruit various.......... XIII. *Malvaceæ*, p. 312

FF. Petals and stamens borne on a disk or rim surrounding the pistil: ovary superior.

G. Herbs ....XIV. *Geraniaceæ*, p. 313

GG. Trees or shrubs ....XV. *Sapindaceæ*, p. 315

FFF. Petals and stamens borne on the calyx or on a hollow calyx-like torus.

G. Ovary superior, except in the pear tribe (Rosaceæ)

H. Fruit a legume............XVI. *Leguminosæ*, p. 316

HH. Fruit not a legume: stamens 20 or more...... XVII. *Rosaceæ*, p. 319

GG. Ovary distinctly inferior.

H. Flowers corymbose or paniculate, showy...... XVIII. *Saxifragaceæ*, p. 323

HH. Flowers in umbels, small..XIX. *Umbelliferæ*, p. 325

DD. Gamopetalæ: corolla in one piece, at least towards the base (as if petals were more or less united).

E. Ovary superior.

F. Fruit of 4 nutlets, produced from a 4-lobed ovary... XX. *Labiatæ*, p. 326

FF. Fruit not a nutlet, usually capsular (sometimes a berry).

G. Corolla regular.

H. **Plant twining: corolla twisted in bud.........**
XXI. ***Convolvulaceæ*, p. 328**

HH. **Plant not twining: corolla plaited or folded in the bud...............XXII. *Solanaceæ*, p. 329**

GG. **Corolla irregular (nearly regular in verbascum).**
XXIII. ***Scrophulariaceæ*, p. 331**

EE. **Ovary inferior.**

F. **Anthers distinct: fls. not in heads................**
XXIV. ***Caprifoliaceæ*, p. 333**

FF. **Anthers syngenesious: fls. in dense heads.........**
XXV. ***Compositæ*, p. 334**

A. CRYPTOGAMS.

I. FÍLICES. Ferns.

Herbaceous and leafy plants, ours without stems or trunks above ground, but producing perennial rootstocks: plants flowerless and seedless, but bearing spores in sporangia, the latter collected into sori which are usually borne on the under side or margins of the fronds and which are sometimes covered with an indusium.—Most abundant in warm countries, of about 4000 species, of which about 165 are native to the United States. The leaflets of fern-fronds are *pinnæ*; the secondary leaflets are *pinnules*.

A. Fruit borne in contracted panicles or on specially contracted parts of the frond, these parts being devoid of resemblance to green leaves.

B. Sporangia large and globose, without a ring of special cells running around their margin................1. ***Osmunda***

BB. Sporangia with a ring of prominent elastic cells running around the margin, and which are concerned in the dehiscence (as in Fig. 307)..................2. ***Onoclea***

AA. Fruit borne on the back of green fronds (the fruiting pinnæ sometimes narrowed but still leaf-like, as in Fig. 305): sporangia with a ring of elastic cells.

B. Sori naked (no indusium)..........................3. ***Polypodium***

BB. Sori borne under the reflexed margins of the frond.

C. Pinnæ entire on the lower edge, somewhat triangular in outline..............................4. ***Adiantum***

CC. Pinnæ toothed on both margins, oblong in outline...5. ***Pteris***

BBB. Sori covered with a distinct scale-like indusium.

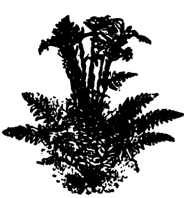
C. Shape of sori oblong..............................6. ***Asplenium***

CC. Shape circular, indusium peltate or nearly so......7. ***Dryopteris***

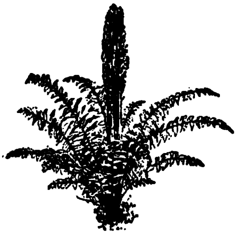
1. **OSMÚNDA.** Flowering Fern.

Strong ferns from stout creeping rootstocks, with large pinnate fronds: sporangia covered with interwoven ridges, but wanting the elastic ring of most ferns. Inhabitants of bogs and wet woods.

O. regàlis, Linn. *Royal fern.* Top of the frond contracted into a fruiting panicle: frond 2-pinnate, the pinnæ oblong, obtuse, and nearly entire.



418. Osmunda Claytoniana.



419. Osmunda cinnamomea.

O. Claytoniàna, Linn. Fig. 418. Two to four pairs of pinnæ near the middle of the frond contracted into fruit-bearing parts: pinnæ linear-lanceolote and acute, deeply lobed.

O. cinnamòmea, Linn. *Cinnamon fern.* Fig. 419. Some fronds entirely contracted into fruiting parts, and these cinnamon color (whence the vernacular name): sterile form with the fronds much like those of *O. Calytoniana* in shape except more acute at top.

2. **ONOCLÈA.** Sensitive Fern.

Mostly rather strong ferns, with broad sterile fronds and with the fertile fronds rolled into hard contracted fruiting bodies, which remain after the sterile leafy fronds have perished: sporangia with an elastic marginal ring of cells. Bogs and old springy fields.

O. sensíbilis, Linn. *Sensitive fern. Brake.* Fig. 310. Sterile frond triangular-ovate, the pinnæ not extending quite to the midrib and toothed: fertile frond usually lower than the other (1–2 ft. high), with a few pinnæ. Common in old pastures.

O. Struthiópteris, Hoffm. *Ostrich fern.* Very tall (2–5 ft.), the sterile fronds narrow, once-pinnate, with long-lanceolate acute lobed pinnæ: fertile fronds much shorter, blackish, with many pinnæ.

3. **POLYPÒDIUM.** Polypody.

Small ferns, with simple or once-pinnate fronds from slender creeping rootstocks: sori round, borne at the ends of little veins. On dry cliffs.

P. vulgàre, Linn. *Common polypody* or *polypode.* Figs. 306, 307. Fronds a foot or less tall, narrow-oblong in outline, pinnatifid, the lobes nearly or quite entire: fertile pinnæ not contracted.

4. **ADIÁNTUM.** Maidenhair Fern. Fig. 309.

Small ferns with compound forking fronds and wedge-shaped or somewhat triangular pinnæ, shining stipes or petioles, and sori borne at the ends of the veins under the reflexed margins of the pinnæ.

A. pedàtum, Linn. *Common maidenhair.* Plant 2 ft. or less high, the leaves forking into several or many long pinnæ which bear broad pinnules notched on the upper margin. Cool, shady woods. Very graceful.

5. **PTÈRIS.** Brake.

Coarse ferns of mostly dryish places, with long pinnæ: sporangia borne beneath the reflexed margin of the pinnules, on small, transverse veins.

P. aquilìna, Linn. *Common brake.* Figs. 125, 308. Fronds broadly triangular, twice- or thrice-pinnate, the pinnules long-lanceolate, acuminate, and lobed. Common in sunny places: perhaps our commonest fern. Two to 3 ft. high, growing in patches, particularly in burned areas.

6. **ASPLÈNIUM.** Spleenwort.

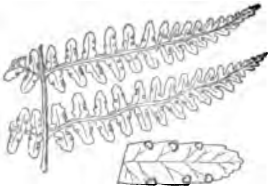
Middle-sized ferns, mostly with pinnate leaves: sori oblong or linear, borne on the upper side of a veinlet, or back to back on opposite sides of the veinlet, these veinlets not interwoven.

A. Fìlix-fœ́mina, Linn. *Lady-fern.* Large, the fronds 2–3 ft. tall, growing many together, twice-pinnate, the pinnules oblong-pointed and sharp-toothed: sori short and close together, at maturity becoming more or less continuous. A very common fern in moist woods and copses.

7. **DRYÓPTERIS.** Shield-fern.

Much like the last in general appearance, but the sori circular and covered with peltate or reniform indusia.

D. acrostichoides, Kuntze. (*Aspidium acrostichoides,* Swartz). *Christmas fern.* Figs. 304, 305. Fronds 2 ft. or less tall, narrow, once-pinnate, the pinnæ serrate and bearing a larger tooth on the upper side near the base, the terminal part of the frond somewhat contracted in fruit. Common in woods. Nearly or quite evergreen.



420. Dryopteris marginalis.

D. Thelýpteris, Gray. (*Aspidium Thelypteris,* Swartz). *Marsh shield-fern.* Fronds standing 2 ft. high, long-pointed, once-pinnate, the pinnæ many-lobed, the margins of the fertile fronds revolute.

D. marginàlis, Gray. Fig. 420. Large, handsome fern growing in woods and ravines, 2 ft. high: fronds once-pinnate, the pinnæ pinnatified and lance-acuminate: sori large and close to the margin of the frond: petiole chaffy.

AA. PHENOGAMS: GYNOSPERMS.

II. CONÍFERÆ. Cone-bearing or Pine Family.

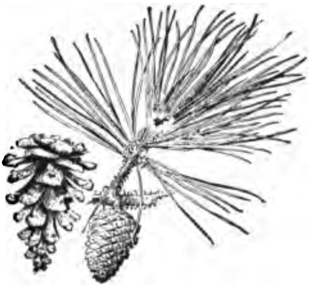
Woody plants, mostly trees, with resinous sap and stiff needle-shaped or scale-like, mostly evergreen leaves: plants bearing no ovaries, the ovules lying naked and receiving the pollen directly: flowers diclinous (usually monœcious), generally in scaly catkins, those catkins bearing the pistillate flowers maturing into cones but sometimes becoming berry-like (as in junipers). Above 300 species, one-third of which inhabit North America: particularly abundant in elevated and mountainous regions.

A. Cone dry, with overlapping scales.
  B. Scales many and cones 1 in. or more long.
    C. Leaves long and needle-like, in sheaths or bundles of 2 to 5, persistent................................1. *Pinus*
    CC. Leaves short, scattered, persistent.
      D. In cross-section, lvs. 4-sided: sessile..............2. *Picea*
      DD. In cross-section, lvs. flat: short-petioled..........3. *Tsuga*
    CCC. Leaves short but very slender, in clusters, deciduous.4. *Larix*
  BB. Scales few (3–12), the cones about ½ in. long..........5. *Thuja*
AA. Cone modified into a fleshy, berry-like body.............6. *Juniperus*

1. **PÌNUS.** PINE.

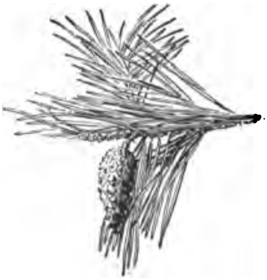
Trees with long, persistent, needle-shaped, angled leaves, in bundles of 2 to 5, and with scale-like deciduous leaves on the young branchlets: sterile catkins usually borne at the base of the new shoot: fertile cones maturing the second year, often hanging on the tree for years: cotyledons several.

P. Stròbus, Linn. *White pine.* Figs. 145, 272. Large forest tree, much used for lumber: leaves long and soft, light green, in 5's: cones long and symmetrical, with thin-edged scales, terminal on the shoots and falling after shedding the seeds. Grows as far south as Georgia.



421. Pinus rigida.
Old open cone at the left.

P. palústris, Mill. *Long-leaved pine.* Very tall tree, with nearly smooth bark: leaves very long and slender (usually a foot or more), clustered at the ends of the branches, in 3's: cones 6 in. or more long, the scales tipped with a short curved spine. Lumber tree. Virginia, south.



422. Pinus sylvestris.

P. rígida, Mill. *Pitch pine.* Fig. 421. Medium sized or small tree with rough dark bark: leaves short and stiff, usually in 3's: cone 2–3 in. long. conical, the scales with a short spine. Grows as far south as Va.; common in pine barrens of the north Atlantic coast. An eastern species.

P. sylvéstris, Linn. *Scotch pine.* Fig. 422. Medium-sized tree, with glaucous-green leaves in 2's: cone short, the scales tipped with a prickle or point. Europe; very commonly planted.

P. Austriaca, Höss. *Austrian pine.* Fig. 423. Large tree with very rough bark, and long, dark green stiff leaves (about 6 in. long) in 2's: cone about 3 in. long, the scales not prickly. Europe, commonly planted; a coarser tree than the Scotch pine.

423. Pinus Austriaca.

2. PÌCEA. SPRUCE.

Trees of medium or large size, with short, scattered leaves: cones maturing the first year, hanging at maturity, their scales thin.

P. excélsa, Link. *Norway spruce.* Figs. 270, 271. Becoming a tall tree: cones 5–7 in. long, the large scales very thin-edged. Eur., but the commonest of planted evergreens. Until 25 to 40 years old, the trees are symmetrical cone-shaped specimens, holding their lower branches.

P. nigra, Link. *Black spruce.* Fig. 424. Becoming a middle-sized tree, with dull, dark foliage: cones 1½ in. or less long, usually hanging for several years, the edges of the scales often irregular. Cold woods, as far south as North Carolina in the mountains.

3. TSÙGA. HEMLOCK SPRUCE.

Differs from Picea in having flat 2-ranked petioled leaves: cones hang-on the end of last year's branches.

T. Canadénsis, Carr. *Hemlock.* Fig. 425. Large forest tree, with deep-furrowed, dark bark and coarse wood: leaves whitish beneath: cones not an inch long, compact. Common lumber tree. Bark much used in tanning.

424. Picea nigra.

4. LÀRIX. LARCH.

Trees of medium size: leaves soft, short, in fascicles or clusters on short branchlets, falling in autumn: cones much like those of Picea, but standing erect at maturity.

L. decidua, Mill. (*L. Europœa, DC.*). *European larch.* Leaves 1 in. long: cones of many scales, about 1 in. long. Planted for ornament and timber.

L. Americàna, Michx. *Tamarack. Hackmatack.* Leaves shorter and pale in color: cones of few scales, ½ in. or less long. Swamps.

425. Tsuga Canadensis.

5. THÙJA. ARBOR-VITÆ.

Trees, becoming large: leaves opposite, closely appressed to the branchlets, the latter frond-like: cones small, oblong or globular, of few scales. Leaves awl-like on new growths and scale-like on the older growths.

T. occidentàlis, Linn. *Arbor-vitæ. White cedar* of some places. Fig.

426. Cones ½ in. or less long, bearing 2-winged seeds. Swamps and cold woods, as far south as North Carolina in the mountains. Very commonly planted as a hedge evergreen and as single specimens, but in the wild becoming very large trees and much used for telegraph poles.

426. Thuja occidentalis.

6. JUNÍPERUS. Juniper.

Small trees or shrubs, with opposite or whorled awl-like leaves (often of two kinds): fertile catkin of 3–6 fleshy scales which cohere and form a berry-like fruit containing 1–3 hard seeds.

J. commùnis, Linn. *Common juniper.* Shrub, erect or usually spreading and lying close to the ground, with leaves in whorls of 3 and all alike (awl-like): berries large and smooth. Banks and sterile ground.

J. Virginiàna, Linn. *Red cedar. Savin.* Small tree or large shrub, usually narrow pyramidal in growth, with leaves of two kinds (scale-like and awl-like, the former small and lying close to the branch): berry glaucous: heart-wood red and highly scented. Common on banks and in old fields.

B. PHENOGAMS: ANGIOSPERMS: MONO-COTYLEDONS.

III. ARÀCEÆ. Arum Family.

Perennial herbs, with rhizomes or corm-like tubers and acrid juice: flowers minute, often diclinous and naked, borne on a spadix and surrounded or attended by a spathe: fruit usually a berry, the entire spadix usually enlarging and bearing the coherent berries in a large head or spike. Many tropical plants, and some of temperate regions, many of them odd and grotesque. Genera about 100; species about 1000. Representative plants are skunk cabbage, jack-in-the-pulpit, calla, caladium, anthurium. Leaves often netted-veined.

A. Leaves compound.......................................1. *Arisæma*
AA. Leaves simple.
  B. Spathe hooded or roofed at the top.................2. *Symplocarpus*
  BB. Spathe open or spreading at the top.................3. *Richardia*
  BBB. Spathe open and spreading for its whole length.....4. *Calla*

1. ARISǼMA. Indian Turnip. Jack-in-the-Pulpit.

Stem arising from a corm-like tuber, and bearing 1 or 2 compound leaves with sheathing petioles: flowers naked and diclinous, the pistillate at the base of the spadix and the staminate above them, the top of the spadix not flower-bearing: staminate flowers of a few sessile anthers, and the pistillate with 1 sessile ovary which ripens into a red few-seeded berry. Plants of spring or early summer, in rich woods. Tuber very pungent, often used in domestic medicine.

A. triphýllum, Torr. *Jack-in-the-Pulpit. Common Indian Turnip.* Fig. 226. Leaves usually 2, each bearing 3 oblong-elliptic pointed leaflets: spathe purple-striped, curving over the spadix.

A Dracóntium, Schott. *Dragon-root.* Leaf usually 1, with 7–11 narrow oblong leaflets: spathe greenish, shorter than the spadix.

2. SYMPLOCÁRPUS. Skunk Cabbage.

Leaves and flowers arising from a strong rootstock, the lvs. very large and appearing after the spathes: fls. perfect, each with 4 sepals, 4 stamens and single ovary which is sunk in the fleshy spadix: fruit made up of the fleshy spadix with imbedded fleshy seeds: spathe pointed and arching, inclosing the spadix. Common in wet meadows in the northeastern states.

S. fœ́tidus, Salisb. Spathes purple, arising in the earliest spring: leaves very large (often 2 ft. long), simple and entire, ovate, in tufts. The tufted leaves and fetid odor give the plant the name of skunk cabbage.

427. Richardia Africana.

3. RICHÁRDIA. Calla Lily.

Leaves several from each short rootstock, their petioles sheathing the flower-scape: flowers naked and diclinous, the stamens above and the 3-loculed ovaries below on the spadix: spathe large and showy, the top flaring and the base rolling about the spadix. Several species are cultivated, but the following is the only common one:

R. Africàna, Kunth. *Calla* or *Calla lily* of gardens. Fig. 427. Leaf-blades broadly arrow-shaped, simple and entire, cross-veined, glossy: spathe white and wax-like. Cape of Good Hope.

428. Calla palustris.

4. CÁLLA.

Differs from the above in having a spathe which does not inclose the spadix, and mostly perfect flowers (the upper ones sometimes staminate), each of 6 stamens and 1 ovary: fruit a red berry. One species:

C. palústris, Linn. *True Calla.* Fig. 428. Leaves about 1 ft. high, the blades arrow-shaped: spathe about 2 in. long, white on the upper face. In cold bogs, north.

IV. LILIÀCEÆ. Lily Family.

Herbs, with bulbs, corms, or large rootstocks: fls. mostly regular and showy, the perianth of six separate or coherent parts, the stamens usually six and standing in front of the parts of the perianth: ovary superior, usually 3-loculed, ripening into a capsule or berry. About 200 genera, including more than 2,000 widely distributed species. Characteristic plants are lily, lily-of-the-valley, onion, Solomon's seal, tulip, trillium, hyacinth, asparagus, yucca.

A. Fruit a loculicidal capsule: style 1.
B. Plant bulbous: root-leaves not in large clumps.
C. Stem tall and leafy.............................. 1. *Lilium*
CC. Stem shorter, with only 2 to 6 leaves.
D. Flower erect.................................. 2. *Tulipa*
DD. Flower nodding.............................. 3. *Erythronium*
CCC. Stem naked, bearing many flowers............. 4. *Hyacinthus*
BB. Plant with a rootstock, and large clumps of leaves.
C. Flowers yellow, paniculate on a somewhat branching scape.................................. 5. *Hemerocallis*
CC. Flowers white or blue, mostly in a simple raceme. 6. *Funkia*
AA. Fruit an angled berry: styles or stigmas 3: leaves broad and netted-veined.......................... 7. *Trillium*
AAA. Fruit a globular berry: style 1: fls. small, white, or greenish.
B. Foliage made up of cladophylla, the true leaves being mere scales: stamens borne on the base of the small corolla........................... 8. *Asparagus*
BB. Foliage of ordinary leaves: stamens borne on the corolla-tube.
C. Perianth of 6 separate parts.................... 9. *Smilacina*
CC. Perianth gamopetalous, with 6 lobes.
D. Flowers racemose on a scape................10. *Convallaria*
DD. Flowers hanging from the axils of leaves...11. *Polygonatum*

1. LÍLIUM. Lily.

Strong-growing bulbous herbs, with leafy stems usually bearing several or many flowers: perianth bell-shaped or funnelform, the 6 divisions nearly or quite separate and spreading or recurving and having a honey-bearing groove at the base: anthers attached by the middle (versatile).

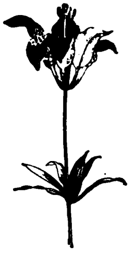
a. *Flowers white.*

L. longiflòrum, Thunb. *Easter lily.* One to 4 ft., with scattered long-lanceolate pointed leaves: flowers 5–8 in. long, horizontal, scarcely widened from the base to the middle, fragrant. Japan and China, now much cultivated under glass. Many of the bulbs are grown in the Bermuda Islands, whence the name "Bermuda lily."

L. cándidum, Linn. *Common white lily.* Leaves broad-lanceolate, scattered: flowers numerous, 5 in. or less long, widening gradually from the base. Europe. Common in gardens.

aa. *Flowers in shades of yellow or orange.*

L. Philadélphicum, Linn. Fig. 429. Flowers 1 to 3, erect, 2–3 in. long, orange-red and spotted, the divisions separate: leaves whorled. Dry soil.

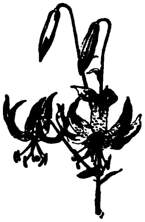


429. Lilium Philadelphicum.

L. Canadénse, Linn. Two to 5 ft., with leaves in whorls and bulbs producing rhizomes or runners: fls. several or many, erect or horizontal on long stalks, the divisions spreading above the middle, orange or red and spotted. Meadows and swales.

L. supérbum, Linn. Fig. 430. Very tall, bearing several or many nodding red-orange spotted flowers in a panicle, the segments all pointing backwards. Meadows and low grounds.

L. tigrinum, Andr. *Tiger lily.* Fig. 30. Four to 5 ft., bearing a loose cottony covering on the stems: leaves sessile, scattered, lanceolate: flowers many, nodding in a panicle, orange-red and black-spotted, the divisions about 4 in. long and rolled back. China and Japan; old gardens.



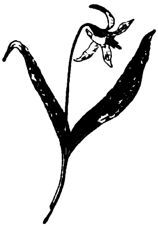
430. Lilium superbum.

2. **TÙLIPA.** Tulip.

Low bulbous plants with a few leaves near the ground on the 1-flowered stem: flower large, erect, the 6 divisions erect or flaring: capsule triangular.

T. Gesneriàna, Linn. *Common tulip.* Leaves 3–6, broad: peduncle glabrous: divisions of the flower broad at the end, with a very short point in the center: late-blooming tulips, originally from Asia Minor.

T. suavèolens, Roth. *Duc Van Thol tulip.* Early and dwarf, with fewer leaves, downy peduncle, and acuminate segments. Caspian Sea; common in cultivation.



431. Erythronium Americanum.

3. **ERYTHRÒNIUM.** Dog's-tooth Violet.

Low herbs with deep-seated conical bulbs, and scape with 2 leaves near the ground: flower nodding, the 6 divisions wide-spreading or recurved, the style long and club-shaped. Blooming in earliest spring.

E. Americànum, Smith. *Common dog's-tooth violet,* or *adder's tongue.* Fig. 431. Leaves thickish, oblong-lanceolate, mottled with purple: flower light yellow, nodding on a stem 3–6 in. tall. Low grounds.

E. álbidum, Nutt. *White adder's tongue.* Leaves scarcely mottled: flowers whitish. Low grounds.

4. **HYACÌNTHUS.** Hyacinth.

Low plants, with large bulbs, producing many flowers in spikes or dense racemes on a short scape, the leaves arising directly from the bulb: flowers bell-shaped or funnelform, the 6 lobes spreading or curling back.

H. orientàlis, Linn. *Common hyacinth.* Fig. 174. Early spring, the flowers of many colors and sometimes double, the perianth-tube swollen, the oblong-spatulate lobes as long as the tube. Greece to Asia Minor.

Var. **álbulus,** Baker. *Roman hyacinth.* Flowers fewer and usually smaller, white or nearly so, the perianth-tube scarcely swollen and the lobes shorter. France. Much cultivated.

5. **HEMEROCÁLLIS.** YELLOW DAY-LILY.

Strong-growing plants from tuberous roots, producing clumps of long sword-shaped leaves: flowers yellow or orange, erect, large and lily-like, in clusters or panicles on a tall, branching scape, the divisions widely spreading at the top. Old World, but common in gardens.

H. fúlva, Linn. *Orange day-lily.* Flowers tawny orange, produced in early summer, the inner perianth divisions nearly or quite obtuse. The commonest species, and often escaped along roadsides.

H. flàva, Linn. *Yellow day-lily.* Plant somewhat smaller, early-blooming: flowers fragrant, pure lemon-yellow, inner divisions acute.

432. Funkia subcordata.

6. **FÚNKIA.** WHITE and BLUE DAY-LILY.

Medium-sized plants, producing dense clumps of broad-bladed leaves from rootstocks: flowers blue or white, in racemes on scapes, each flower sheathed at the base by 1 or 2 bracts, the perianth-tube long and the limb sometimes irregular. China and Japan; planted by houses and along walks.

F. subcordàta, Spreng. *White day-lily.* Fig. 432. Leaves broadly cordate-ovate: flowers large and white, in a short raceme, not drooping.

F. ovàta, Spreng. (*F. cœrùlea,* Sweet). *Blue day-lily.* Fig. 433. Leaves broadly ovate: flowers deep blue, in a long raceme, nodding.

433. Funkia ovata.

7. **TRÍLLIUM.** WAKE-ROBIN.

Low herbs from deep-seated corm-like tubers: leaves 3 in a whorl, broad and netted-veined: flower single, of 3 colored petals and 3 green sepals, the latter persistent until the angled, many-seeded berry ripens: stigmas 3, often sessile. Plants of earliest spring, growing in rich woods.

a. *Flower sessile in the leaf-whorl.*

T. séssile, Linn. Flowers dull purple, the parts narrow, pointed, and nearly erect: leaves sessile, ovate, often blotched with purple. Pa.,W. and S.

aa. *Flower stalked in the leaf-whorl.*

T. grandiflòrum, Linn. *Common wake-robin,* or *birthroot.* Fig. 221. Flowers large and white, the peduncle standing erect or nearly so, the petals broadest above the middle (obovate) and 2–2½ in. long: leaves broad-ovate, sessile or nearly so. Flowers become rose-pink with age.

T. eréctum, Linn. Flowers smaller, ill-scented, varying from white to pink and purple, the peduncle erect or declined, the petals ovate or lanceolate and spreading: leaves broad-ovate. Frequent north, and south to Tenn.

T. cérnuum, Linn. Flowers not large, white, the peduncle declined under the broad leaves; petals ovate-lanceolate, rolled back. Range of the last.

8. ASPÁRAGUS. Asparagus.

Mostly tall, often climbing plants with cladophylla and very small scale-like true leaves: flowers white or greenish, small, bell-shaped, scattered or in groups of 2 or 3: fruit a 3-loculed and 1–6-seeded small berry.

A. officinàlis, Linn. *Common asparagus.* Figs. 147, 148. Erect and branchy, the strong young shoots thick and edible: berries red. Eur.

A. plumòsus, Baker. Fig. 149. Twining, with dark, frond-like foliage, small white flowers and black berries. S. Africa; greenhouses.

434.
Asparagus medeoloides.

A. medeoloides, Thunb. *Smilax* of florists (but not of botanists). Fig. 434. Twining: foliage broad and leaf-like: fls. solitary and fragrant: berries dark green. S. Africa; much grown by florists.

9. SMILACÌNA. False Solomon's Seal.

Low, erect plants with many small white flowers in racemes or panicles: perianth 6-parted: fruit a 3-loculed berry: rootstock creeping.

S. racemòsa, Desf. *False spikenard.* About 2 ft., tall, somewhat downy, with many oblong or oval leaves: flowers in a panicle: berries pale red, speckled. Spring and early summer. Rich woods.

S. stellàta, Desf. Nearly or quite smooth: leaves narrower: flowers in a simple raceme. Forms patches in low ground.

10. CONVALLÀRIA. Lily-of-the-valley.

Low, spring-flowering herbs from branching rootstocks: flowers gamopetalous, white and waxy, nodding in a 1-sided raceme, the 6 short lobes recurving: fruit a red berry.

C. majàlis, Linn. Leaves oblong, numerous from the rootstocks, forming mats, and about 2 with each scape: flowers very fragrant. One of the best known garden flowers. Europe. The only species.

11. POLYGONÀTUM. Solomon's Seal.

Mostly strong plants from long running rootstocks on which the scars of preceding stalks are very evident (whence the common name): stems leafy, bearing nodding gamopetalous flowers in the axils: fruit a globular, dark-colored berry. Rich woods; spring,

P. gigantèum, Dietr. Three to 5 ft. tall: leaves ovate, somewhat clasping: peduncles in each axil 2–8 flowered: filaments not roughened.

P. biflòrum, Ell. One–3 ft.: leaves oblong, nearly sessile, somewhat glaucous: peduncles usually 2-flowered: filaments roughened.

V. AMARYLLIDÀCEÆ. Amaryllis Family.

Differs from Liliaceæ chiefly in having an inferior ovary and in bearing its flowers more uniformly on scapes. More than 600 species in nearly 70 genera, widely dispersed. Representative plants are narcissus, daffodil, snowdrop, tuberose, amaryllis lilies. Plants of the first three genera may be grown from bulbs in the school-room.

A. Stem a leafless scape.
  B. Perianth with a crown or cup in its center...............1. *Narcissus*
  BB. Perianth with no cup.
    C. Anthers and style pointed...........................2. *Galanthus*
    CC. Anthers and style blunt............................3. *Leucoium*
AA. Stem tall and leafy.......................................4. *Polianthes*

1. NARCÍSSUS. Narcissus. Daffodil.

Low plants producing from 1 to many 6-parted flowers on a scape which arises from a tunicated bulb: perianth with a long tube and bearing a cup or crown in its center. Old World, but frequently cultivated.

a. *Crown as long as, or longer than, the divisions of the perianth.*

N. Pseùdo-Narcíssus, Linn. *Trumpet narcissus. Common daffodil.* Fig. 234. Scape 1-flowered, the flower large and yellow with a relatively short tube and a wavy-edged crown. Leaves flat and glaucous. Double forms are common in gardens.

aa. *Crown half or more as long as the divisions of the perianth.*

N. incomparábilis, Curt. Scape 1-flowered. the flower about 2 in. or more across, yellow, the cylindrical tube 1 in. long, the crown plaited and usually a deeper yellow: leaves flat and glaucous.

aaa. *Crown less than half the length of the division.*

N. Tazétta, Linn. *Polyanthus narcissus. Chinese sacred lily.* Fig. 435. Flowers several to many in an umbel, yellow or white, small, the crown usually darker colored and usually somewhat scalloped: leaves flat and somewhat glaucous. One of the commonest kinds. The narcissus known to florists as "Paper-white" is a white-flowered form of this species.

N. poéticus, Linn. *Poet's narcissus.* Scape rather slender, usually 1-flowered, the flower white with the thick rim of the very short crown margined with red: leaves flat, glaucous.

435.
Narcissus Tazetta.

N. Jonquílla, Linn. *Jonquil.* Scape 2–5-flowered, the flowers small and yellow, the tube slender and the segments wide-spreading: leaves linear, somewhat cylindrical.

2. **GALÀNTHUS.** SNOWDROP.

Small, spring-blooming plants, with a single white flower nodding from the top of the scape, followed by grass-like leaves: perianth divisions 6, oblong and more or less concave, the three inner ones shorter, some of them usually green-blotched at the tip: anthers and style pointed.

436. Galanthus nivalis.

G. nivàlis, Linn. *Snowdrop.* Fig. 436. One of the earliest of spring flowers, appearing as soon as the snow is gone, the flower and leaves arising from a small bulb: scape 6 in. or less high: inner divisions of the bell-shaped flower tipped with green. Europe.

3. **LEUCÒIUM.** SNOWFLAKE.

Flowers often more than 1: divisions of the perianth all alike: anthers and style blunt: otherwise very like Galanthus.

L. vérnum, Linn. *Snowflake.* Taller than the snowdrop (about 1 ft.), the scape usually 1-flowered, blooming later, the flowers larger. Europe.

4. **POLIÀNTHES.** TUBEROSE.

Leafy-stemmed lily-like plants, with a thick, tuberous rootstock (whence the name *tuber-ose* not *tube-rose*), bearing an erect spike of white flowers: perianth with a short slightly curved tube and 6 spreading nearly equal divisions: stamens included in the tube (not projecting).

P. tuberòsa, Linn. *Tuberose.* Two to 3 ft., bearing long-linear, channelled, many-ranked leaves: flowers very fragrant, sometimes tinted with rose. A popular garden plant from Mexico, blooming in the open in late summer and autumn; some forms are double.

VI. IRIDÀCEÆ. IRIS FAMILY.

Differs from Amaryllidaceæ and Liliaceæ in its inferior ovary, three stamens which are opposite the outer parts of the perianth, and 2-ranked equitant (bases overlapping) leaves: stigmas sometimes large and petal-like. About 60 genera and 700 species. Representative plants are iris or blue flag, crocus, gladiolus, freesia. Crocuses and freesias are easily grown in window-boxes for winter and spring bloom.

A. Lobes of the style flat and colored, looking like petals......1. *Iris*
AA. Lobes of the style thread-like.
  B. Plant stemless, the leaves and flowers arising directly from the corm..2. *Crocus*
  BB. Plant with a leaf-bearing and flower-bearing stem.
    C. Flowers in a short 1-sided cluster: plant small.......3. *Freesia*
    CC. Flowers in a terminal spike: plant large..............4. *Gladiolus*

1. **IRÍS.** FLEUR-DE-LIS. FLAG.

Mostly strong plants, with rhizomes or tubers: flowers mostly large and showy, the three outer segments recurving and the three inner ones usually smaller and more erect or sometimes incurving: the three long divisions of the style petal-like and often more or less hairy, covering the stamens: stigma on the under side of the style: leaves long and sword-shaped. Several wild and many cultivated species. The following species have rhizomes.

a. *Flowers yellow.*

I. Pseudácorus, Linn. *Common yellow flag.* One to 3 ft., with several-flowered, often branching stamens: outer divisions of the perianth with no hairs or crests: flowers bright yellow. Europe.

aa. *Flowers in shades of blue (sometimes varying to white).*

I. versícolor, Linn. *Common wild blue flag.* Two to 3 ft., stout: leaves ¾-in. wide, flat: flowers about 3 in. long, short-stalked, violet-blue, the tube shorter than the ovary, the inner petals small and the outer ones with no hairs. Swamps.

I. lævigàta, Fisch. & Mey. (*I. Kæmpferi*, Sieb.). *Japan iris.* Two to 3 feet, the stem much overtopping the thin, broad leaves: flowers large (sometimes several inches across), flat, the inner lobes spreading, the outer ones very large and rounded, with no hairs or crests: color mostly in shades of blue and purple. Japan; now one of the choicest of garden irises.

437. Iris Germanica.

438. Crocus vernus.

439. Freesia refracta.

I. Germánica, Linn. *Common blue flag* of gardens (sometimes runs wild). Fig. 437. Two to 3 feet, with long sword-shaped leaves: flowers few or several to each stem, about 3 to 4 in. across, the drooping outer segments with yellow hairs, the inner segments erect and arching inwards. Europe.

2. **CRÒCUS.** CROCUS.

Small, stemless plants, the long-tubed flowers and the grass-like leaves arising directly from the coated corm: flowers with the 6 obovate divisions all alike and erect-spreading or the inner ones a little the smaller, opening only in sunshine. The following, from Europe, blooms in earliest spring.

C. vérnus, Linn. *Common crocus.* Fig. 438. Leaves 2–4 to each flower, glaucous on the under side: flower rising little above the ground; color in shades of lilac and variously striped, sometimes white.

3. FREÈSIA. Freesia.

Small cormous plants with flat leaves: flowers white or yellowish, tubular, with a somewhat spreading limb, the tube generally curved: stem about 1 ft. high, bearing several erect flowers on a sidewise cluster. Popular florists' plants of easy culture and quick growth.

F. refrácta, Klatt. Fig. 439. Leaves narrow: flower usually somewhat 2-lipped or irregular, white in the most popular forms but yellowish in some, often with blotches of yellow; fragrant. Cape of Good Hope.

4. GLADÌOLUS. Gladiolus.

Tall, erect plants, with flat, strong-veined leaves, the stem arising from a corm (Fig. 50): flowers in a more or less 1-sided terminal spike, short-tubed, the limb flaring and somewhat unequal: stamens separate (united in some related genera): style long, with three large stigmas.

440. Gladiolus Gandavensis.

G. Gandavénsis, Van Houtte. Fig. 440. Upper segments of the perianth nearly horizontal: colors various and bright: spikes long. Hybrid of two or more species from the Cape of Good Hope. Summer and fall.

BB. PHENOGAMS: ANGIOSPERMS: DICOTYLEDONS.

C. CHORIPETALÆ.

VII. CUPULÍFERÆ. Oak Family.

Monœcious trees and shrubs with staminate flowers in catkins and the fertile in catkins or solitary: lvs. alternate, with stipules early deciduous (mostly scale-like), and the side-veins straight or nearly so: stamens 2 to many: fruit a 1-seed nut, sometimes inclosed in an involucre. Ten or a dozen genera and upwards of 450 species. Representative plants are oak, chestnut, beech, birch, hazel, ironwood.

A. Sterile flowers in a hanging head: fruits 2 three-cornered nuts in a small, spiny involucre or bur.................1. *Fagus*
AA. Sterile flowers in cylindrical catkins.
  B. Fruit 1 to 4 rounded or flat-sided nuts in a large, sharp-spiny involucre or bur..............................2. *Castanea*
  BB. Fruit an acorn—a nut sitting in a scaly or spiny cup.....3. *Quercus*
  BBB. Fruit flat and often winged, thin and seed-like, borne under scales in a cone
    C. Fertile flowers naked: mature cone-scales thin.........4. *Betula*
    CC. Fertile flowers with a calyx: cone-scales thick........5. *Alnus*

1. FÀGUS. Beech.

Tall forest trees with light bark, and prominent parallel side-veins in the leaves: sterile flowers in a small, pendulous head, with 5–7-cleft calyx and 8–16 stamens: fertile flowers 2, in a close involucre, ripening into 2 three-cornered "beech nuts" in a 4-valved bur.

F. Americàna, Ait. *American beech.* Close-grained, hard-wood tree, with light colored bark: leaves ovate-oblong and acuminate, coarsely serrate, usually with 9 or more pairs of nerves: nuts ripening in the fall, and much sought by boys and squirrels. A common forest tree.

F. sylvática, Linn. *European beech.* Fig. 138. Often planted, particularly in the form of the Purple-leaved and Weeping beech: foliage differs in being mostly smaller, ovate or elliptic, small-toothed, with 9 or less pairs of nerves.

2. CASTÀNEA. CHESTNUT.

Forest trees, with rough, furrowed bark: sterile flowers with 4–7-lobed calyx and 8–20 stamens in very long, erect or spreading catkins, which appear in clusters in midsummer: fertile flowers about 3 in an involucre, producing "chestnuts" in a spiny bur.

C. Americàna, Raf. *American chestnut.* Fig. 241. Tall, straight-grained tree, with large, broad and thin, oblong-lanceolate leaves, which are taper-pointed, and have large teeth with spreading spines: nuts usually 1 in. or less across, sweet. Grows as far west as Mich., and south to Miss.

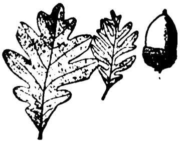
C. sativa, Mill. *European chestnut.* Less tall: leaves smaller and narrower, more pubescent when young, not long-acuminate, the teeth smaller and their spines more incurved: nuts 1 in. or more across, not so sweet as those of the American chestnut. Europe. Very commonly planted.

3. QUÉRCUS. OAK.

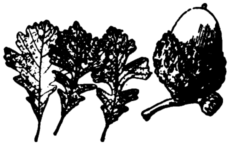
Strong, close-grained trees, with mostly laterally-lobed leaves: sterile flowers in clustered hanging catkins, with a 4–7-lobed calyx, and 3–12 stamens: fertile one in a shallow involucre which becomes the cup of the acorn, the stigma 3-lobed: fruit an acorn. See Fig. 212, which represents the English oak (*Q. Robur*) often planted in choice grounds.

a. *White oak group, distinguished by its light gray scaly bark, rounded lobes or teeth of the leaves, and the acorns maturing the first year.* (*Q. virens* has nearly or quite entire leaves.)

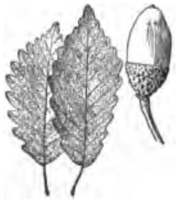
Q. álba, Linn. *White oak.* Fig. 441. Leaves obovate, 5 or 6 inches long, the lobes usually 7 and at equal distances apart, and the sinuses deep or shallow: acorn small, with a rather shallow and not fringed cup. The commonest species.



441. Quercus alba.



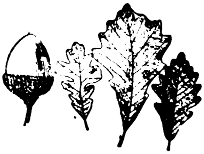
442. Quercus macrocarpa.

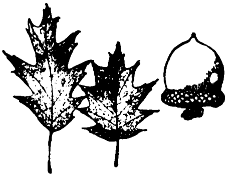


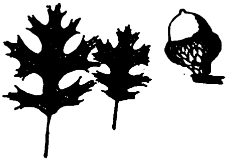
443. Quercus Prinus.

Q. macrocárpa, Michx. *Bur oak.* Fig. 442. Leaves obovate, downy or pale on the lower surface, toothed towards the tips and irregularly and often deeply lobed toward the base: acorn cups heavily fringed on the margins: young branches corky. More common west.

Q. Prinus, Linn. *Chestnut oak.* Fig. 443. Leaves rather long-obovate, toothed, with rounded teeth and yellow-ribbed: acorn long and the cup hard-scaled: bark dark with broad, deep furrows. Eastern.


444. Quercus bicolor.


445. Quercus rubra.


446. Quercus coccinea.

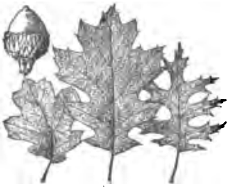
Q. bicolor, Willd. *Swamp white oak.* Fig. 444. Leaves obovate, white-downy on their lower surface, toothed with squarish teeth, the bases wedge-shaped: acorn small, with the margin of the cup finely fringed. Common in low grounds and along ravines.

Q. virens, Ait. *Live oak.* Leaves small, oblong, entire or sometimes spiny-toothed, thick and evergreen: acorn oblong, the nut about one-third covered with its scaly cup. Virginia, south.

aa. *Black oak group, distinguished by its dark furrowed bark, pointed lobes of the leaves, and the acorns maturing the second year.*

Q. rùbra, Linn. *Red oak.* Fig. 445. Leaves obovate or sometimes shorter, the 7–9 lobes triangular and pointing toward the tips: acorn large, flat-cupped. Common.

Q. coccinea, Wang. *Scarlet oak.* Fig. 446. Leaves obovate, bright scarlet in autumn, thin, smooth on the lower surface, the sinuses deep, wide, and rounded: margin of the acorn cup rounding inwards and the scales close: inner bark reddish. Common.


447. Quercus tinctoria.

Q. tinctòria, Bartr. *Black oak.* Fig. 447. Leaves obovate, coarser, downy on the lower surface until midsummer or later, wider towards the tip, the sinuses shallow (or sometimes as in the scarlet oak): margin of the acorn cup not rounding inwards and the scales looser: inner bark orange. Common.

4. **BÉTULA.** Birch.

Small to medium-sized trees, with sterile flowers in drooping, cylindrical catkins, 3 flowers with 4 short stamens being borne under each bract: fertile flowers in short, mostly erect catkins which become cones at maturity, 2 or 3 naked flowers being borne under each 3-lobed bract: fruit winged and seed-like: leaves simple, toothed or serrate: bark often aromatic.

a. *Brown-barked birches: leaves ovate.*

B. lénta, Linn. *Cherry birch. Sweet birch.* Tall tree, the bark tight (not peeling in layers), the twigs very aromatic: leaves oblong-ovate, somewhat cordate at base, doubly serrate, becoming glossy above: bracts of the oblong-cylindric fruiting catkins with wide-spreading lobes. Rich woods.

B. lùtea, Michx. *Yellow* or *gray birch.* Bark grayer or silvery, peeling in layers: leaves scarcely cordate, dull, more downy: bracts of the short-oblong fruiting catkins with scarcely spreading scales: tree less aromatic than the other. Same range.

aa. *White-barked birches: leaves triangular or broad-ovate.*

B. papyrifera, Marsh. *Paper birch. Canoe birch.* Tree of medium to rather large size, with the bark peeling in very large plates or layers: leaves broad-ovate and often somewhat cordate, dull green. Penn., north.

B. populifòlia, Ait. *American white birch.* Small and slender tree with rather tight, glistening, white bark: leaves triangular-acuminate, toothed, dangling, and moving incessantly in the wind. Northeastern states.

B. álba, Linn. *European white birch.* A larger tree, with triangular-ovate leaves which are pointed but not long-acuminate. Europe; the common cultivated white birch.

4. **ÁLNUS.** Alder.

Much like Betula, but smaller trees or bushes: flowers with a 3–5-parted calyx, and the small, short, fertile catkins composed of thickened, woody scales. In the following, the flowers appear before the leaves in earliest spring, from catkins formed the previous year and remaining partly developed during winter. Common along streams.

A. incàna, Willd. *Speckled alder.* Shrub or small tree, with pubescent branches: leaves oval to oblong-ovate, acute, doubly serrate, glaucous and downy underneath: cones about ½ in. long, mostly sessile.

A. rugòsa, Spreng. (*A. serrulata,* Willd.). *Smooth alder.* Leaves elliptic or obovate, acute or rounded at the apex, finely serrate, the under side of the leaves smooth or pubescent only on the veins: cones short-stalked.

A. glutinòsa, Gærtn. *Black alder.* Leaves orbicular or very broadly obovate, not acute, irregularly serrate, dull and nearly smooth beneath: cones peduncled. Europe; planted, some varieties with divided leaves.

VIII. URTICÀCEÆ. Nettle Family.

Trees and herbs, with small apetalous flowers in small clusters or solitary: leaves mostly straight-veined, with stipules: plants diœcious or monœcious, or flowers perfect in the elms: stamens usually as many as the lobes of the calyx and opposite them: ovary superior, ripening into a 1-seeded indehiscent, often winged fruit. A very polymorphous association, by some botanists divided into two or three coördinate families. More than 100 genera and 1500 species. Representatives are elm, hackberry, mulberry, osage orange, nettle, hop, hemp.

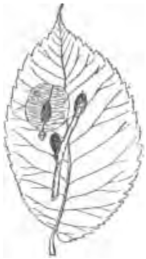
A. Trees.
  B. Fruit a samara..1. *Ulmus*
  BB. Fruit a small drupe..2. *Celtis*
  BBB. Fruit as large as an orange, formed of the whole mass of the pistillate flower-cluster..........................3. *Toxylon*
  BBBB. Fruit resembling a blackberry, formed of the pistillate flower-cluster..4. *Morus*
AA. Herbs.
  B. Leaves digitately lobed or divided.
    C. Plant standing erect...5. *Cannabis*
    CC. Plant twining...6. *Humulus*
  BB. Leaves not lobed: plant with stinging hairs...................7. *Urtica*

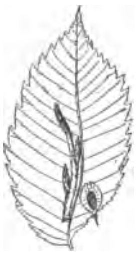
1. ÚLMUS. Elm.

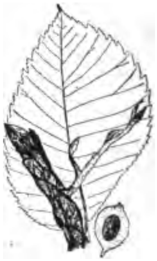
Trees, mostly large and valuable for timber, with rough-furrowed bark: leaves alternate (2-ranked), ovate and straight-veined, dentate: flowers small and not showy, appearing in earliest spring, sometimes diclinous, the calyx 4–9-parted, the anthers 4–9 on long filaments: ovary generally 2-loculed, ripening into a 1-seeded wing-fruit.

a. *Leaves large, rough on the upper surface: fruit large, nearly orbicular.*

U. fúlva, Michx. *Slippery elm.* Fig. 448. Middle-sized or small tree with inner bark mucilaginous or "slippery" in spring: leaves 6–8 in. long and half or more as broad, ovate elliptic and unequal-sided, doubly serrate, very rough above and softer beneath: samara ½–¾ in. long, orbicular or nearly so, with the seed in the center: flowers in dense clusters. Common.


448. Ulmus fulva.


449. Ulmus Americana.


450. Ulmus racemosa.

aa. *Leaves not very rough above: fruit oval, deeply notched at the apex.*

U. Americàna, Linn. *Common* or *white elm.* Figs. 91–95, 146, 449. Tall and graceful tree: leaves elliptic-oval, serrate: samara small, more or less hairy on the thin wing, the notch in the apex extending nearly to the seed: flowers hanging on slender stalks. One of the finest of American trees.

U. racemòsa, Thomas. *Cork elm.* Fig. 450. Smaller tree than the last, with corky-winged branches: leaves with straighter veins: samara with sharp incurved points at the apex: flowers in racemes. Less common.

U. alàta, Michx. *Wahoo elm.* Small tree, with wide, corky ridges on the branches: leaves small and rather thick, almost sessile, ovate to nearly lanceolate and acute: samara downy, at least when young. Virginia, south and west.

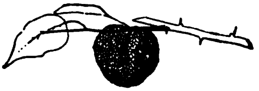
2. **CÉLTIS.** Nettle-Tree. Hackberry.

Elm-like in looks, but the fruit a 1-seeded, berry-like drupe: flowers greenish, in the leaf axils, mostly diclinous; calyx 5–6-parted; stamens 5 or 6: stigmas 2, very long.

C. occidentàlis, Linn. *Common hackberry.* Middle-sized tree with rough-furrowed bark: leaves ovate-pointed, oblique at base, serrate: fruit purplish, as large as a pea, edible in the fall when ripe. Low grounds.

3. **TÓXYLON.** Osage Orange.

Small tree, with diœcious flowers in catkins, and alternate, simple leaves: sterile flowers in raceme-like, deciduous catkins: fertile flowers densely crowded in a head, with 4 sepals and 2 stigmas, the ovary ripening into an akene, the whole flower-cluster becoming fleshy and ripening into an orange-like mass.



451. Toxylon pomiferum.

T. pomiferum, Raf. (*Maclura aurantiaca,* Nutt.). *Osage orange.* Fig. 451. Spiny, low tree, much used for hedges, but not hardy in the northernmost states: leaves narrow-ovate and entire, glossy: flowers in spring after the leaves appear, the fruit ripening in autumn. Mo. and Kan., south.

4. **MÒRUS.** Mulberry.

Small to middle-sized trees, with broad, alternate toothed or lobed leaves and monœcious flowers, with 4-parted calyx: stamens 4, with filaments at first bent inward, the staminate catkins soon falling: fertile flowers ripening a single akene, but the entire catkin become fleshy and blackberry-like, and prized for eating. Leaves very variable, often lobed and not lobed on the same branch.

452. Morus alba.

M. rùbra, Linn. *Common wild mulberry.* Often a large tree in the south: leaves ovate-acuminate, oblique at the base, rough and dull on the upper surface and softer beneath, dentate: fruit ½ in. to 1 in. long, black-red, sweet. Wood yellow. Most abundant south, but growing as far north as Mass.

M. álba, Linn. *White mulberry.* Fig. 452. Leaves light green and usually glossy above, the veins prominent and whitish beneath, the teeth usually rounded or obtuse: fruit of variable size, often 1½ in. long, whitish, violet, or purple. China; planted for ornament and for its fruit, also for feeding silkworms. The much-planted Russian Mulberry is a form of it.

5. **CÁNNABIS.** Hemp.

Tall, strong, diœcious herbs with 5 to 7 leaflets: fertile flowers in clusters, with 1 sepal surrounding the ovary, and 2 long, hairy stigmas: sterile flowers in racemes or panicles, with 5 sepals and 5 drooping stamens.

C. sativa, Linn. *Hemp.* **Six to 10 ft., strong-smelling, blooming all summer: leaflets lanceolate, large toothed. Old World; cultivated for fiber and sometimes escaped in waste places.**

6. **HÙMULUS.** Hop.

Twining diœcious herbs of tall growth, with 5 sepals in the sterile flowers, the stamens erect: fertile flowers with 1 sepal, 2 flowers under each scale of a short, thin catkin which becomes a kind of cone or "hop."

H. Lùpulus, Linn. *Common hop.* **Perennial, rough-hairy: leaves broad-ovate, deeply 3-lobed (only rarely 5–7-lobed): sterile flowers in panicles 2–6 in. long: pistillate catkin enlarging into a "hop" often 2 in. or more long. A native plant, cultivated for hops and sometimes for ornament.**

H. Japónicus, Sieb. & Zucc. *Japanese hop.* **Fig. 167. Annual: leaves not less than 5-lobed: fertile catkin not enlarging into a hop. Japan; much** cultivated for ornament.

7. **ÚRTICA.** Nettle.

Erect herbs with opposite simple leaves and stinging hairs, and monœcious or diœcious flowers in racemes or dense clusters, the calyx of 4 separate sepals: stamens 4: stigma sessile: fruit an ovate flat akene. The following are perennials with flowers in panicled spikes.

U. grácilis, Ait. *Common nettle.* Two to 6 ft.: leaves ovate-lanceolate, serrate, on long petioles. Common in low grounds.

U. diòica, Linn. Not so tall: leaves ovate-cordate and deeply serrate, on rather short petioles, downy underneath. Weed from Europe, very stinging.

IX. POLYGONÀCEÆ. Buckwheat Family.

Herbs, mostly with enlarged joints or nodes and sheaths (representing stipules) above them: leaves simple and usually entire, alternate: flowers small, apetalous, usually perfect and generally borne in spikes or dense clusters: stamens 4–12, attached to the very base of the 3–5-merous calyx: ovary 1-loculed, ripening into a 3–4-angled akene. Thirty or more genera and about 600 widely dispersed species. Characteristic plants are buckwheat, rhubarb, dock, sorrel, smartweed.

A. Root-leaves 1 ft. or more across, rounded .... 1. *Rheum*
AA. Root-leaves narrow or not prominent.
  B. Calyx of 6 sepals, often of two kinds .... 2. *Rumex*
  BB. Calyx of 5 (rarely 4) sepals, all alike.
    C. Flowers white and fragrant .... 3. *Fagopyrum*
    CC. Flowers greenish or pinkish, not distinctly fragrant. 4. *Polygonum*

1. **RHÈUM.** Rhubarb.

Very large-leaved perennials, sending up stout hollow flower-stalks in early summer which bear smaller leaves with sheathing bases: sepals 6, all alike, withering rather than falling, and persisting beneath the 3-winged akene: stamens 9: styles 3. Old World.

R. Rhapónticum, Linn. *Rhubarb. Pie-plant.* Figs. 78, 79. Leaves 1 ft. or more across, the thick petioles eaten: fls. white, in elevated panicles.

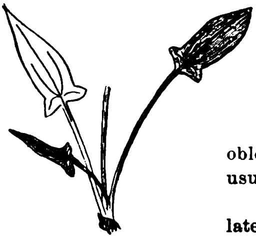
2. **RÙMEX.** Dock. Sorrel.

Perennial often deep-rooted plants with herbage bitter or sour: sepals 6, the 3 outer large and spreading, the 3 inner (known as "valves") enlarging after flowering and one or more of them often bearing a grain-like tubercle on the back: stamens 6, styles 3: flowers in panicles or interrupted spikes.

a. *Docks: herbage bitter: valves often grain-bearing: flowers mostly perfect: leaves not arrow-shaped.*

R. obtusifòlius, Linn. *Bitter dock.* Lower leaves oblong-cordate and obtuse, not wavy: one valve usually grain-bearing. Weed from Europe.

R. críspus, Linn. *Curly dock.* Leaves lanceolate, wavy or curled: all valves usually grain-bearing. Weed from Europe.



453. Rumex Acetosella.

aa. *Sorrels: herbage sour: valves not grain-bearing: flowers diœcious: leaves arrow-shaped.*

R. Acetosélla, Linn. *Common* or *sheep sorrel.* Fig. 453. Low (1 ft. or less): leaves mostly arrow-shaped at base: flowers brownish, small, in a terminal panicle. Common in sterile fields. Europe.

3. **FAGOPÝRUM.** Buckwheat.

Fast-growing annuals, with somewhat triangular leaves, and fragrant flowers in flattish, panicle-like clusters: calyx of 5 parts: stamens 8: fruit a triangular akene. Old World.

F. esculéntum, Mœnch. *Common buckwheat.* Fig. 454. Leaves triangular-arrow-shaped, long-petioled: flowers white, in a compound cluster: akene with regular angles. Flour is made from the grain.

F. Tatáricum, Gaertn. *India wheat.* Slenderer, the leaves smaller and more arrow-shaped and short-petioled: flowers greenish or yellowish, in simple racemes: akene notched on the angles. Somewhat cultivated.

454.
Fagopyrum esculentum.

4. **POLÝGONUM.** Knotweed. Smartweed.

Low weedy plants, or some exotic ones tall and cultivated, blooming in summer and fall, the small pinkish or greenish flowers mostly in racemes or

spikes (in the Knotweeds in the leaf-axils): calyx usually 5-parted: stamens 4–9: stigmas 2 or 3: black akene lenticular or triangular.

a. *Knotweeds: flowers sessile in the axils of the leaves, greenish and very small.*

P. aviculàre, Linn. *Common knotweed. Doorweed.* **Fig. 193. Prostrate or creeping, bluish green wiry plant, growing along the hard edges of walks and in yards, and commonly mistaken for sod: leaves small, mostly oblong, entire: sepals very small, green with a broad white margin: stamens 5 or more: stigmas usually 3. Annual.**

P. eréctum, Linn. *Taller knotweed.* **One ft. or more high: leaves three or four times larger, oblong or oval and obtuse. Common annual.**

455. Polygonum Persicaria.

aa. *Smartweeds; flowers in terminal spikes, mostly pinkish.*

b. *Sheaths of leaves (surrounding stem) hairy on the edge, or the margin with a spreading border.*

P. orientàle, Linn. *Prince's feather.* **Several feet tall, soft-hairy: flowers in long cylindrical nodding spikes: leaves ovate: stamens 7. India; cultivated. Annual.**

P. Persicària, Linn. *Smartweed. Lady's thumb* **(from the dark blotch near the center of the leaf). Fig. 455. About 1 ft.: leaves lanceolate: spikes oblong, dense and erect: stamens usually 6: stigmas 2. Weed from Europe.**

P. Hydropiper, Linn. *Smartweed.* **Herbage very pungent or "smarty:" leaves oblong-lanceolate: spikes short and nodding, the flowers greenish: stamens 6: stigmas 3. Low grounds. Annual.**

P. hydropiperoides, Michx. *Smartweed.* **Herbage not pungent: spikes slender and erect, the flowers whitish: stamens 8: stigmas 3. In very wet places. Perennial.**

P. àcre, HBK. *Smartweed.* **Herbage pungent: leaves linear or lanceolate, long-pointed: spikes slender and erect: flowers white or blush: stamens 8: stigmas 3. Low grounds. Perennial.**

bb. *Sheaths of leaves not hairy, nor the margin bordered.*

P. Pennsylvánicum, Linn. *Smartweed.* **Pungent: plant with conspicuous glandular hairs above: leaves lanceolate: spikes short-oblong and erect, the flowers purplish: stamens 8: stigmas 2. Low ground. Annual.**

X. CARYOPHYLLÀCEÆ. PINK FAMILY.

Herbs, with opposite, mostly narrow, entire leaves without conspicuous veins: flowers 4–5-merous, sometimes apetalous, with stamens twice or less the number of sepals or petals, and 2 to 5 styles which may be wholly separate or partially united: pod usually a 1-loculed

capsule commonly inclosed in the calyx, mostly splitting from the top, the seeds usually attached to a central column. Genera between 30 and 40, species about 1000. Representative plants are pink, carnation, bouncing Bet, catchfly, chickweed, corn-cockle, lychnis, spurrey.

A. Flowers polypetalous, with sepals united into a tube.
  B. Bracts at the base of the calyx.......................... 1. *Dianthus*
  BB. No bracts at base of calyx.
    C. Styles 2.. 2. *Saponaria*
    CC. Styles 4 or 5.. 3. *Lychnis*
AA. Flowers often apetalous, the sepals nearly or quite distinct.
  B. Styles 3 or 4... 4. *Stellaria*
  BB. Styles 5... 5. *Cerastium*

1. DIÁNTHUS. Pink.

Showy-flowered small herbs, with striate, many-furrowed calyx and sepal-like bracts at its base: petals with slender claws or bases, the limb usually toothed or fringed: styles 2.

a. *Flowers single on ends of branches.*

D. Chinénsis, Linn. *China* or *florists' pink.* Leaves short-lanceolate, not grass-like: calyx-bracts linear-acute and as long as the calyx: petals in white and shades of red, very showy. China. Perennial, but grown as an annual (mostly under the florists' name D. Heddewigi).

D. plumàrius, Linn. *Grass* or *Scotch pink. Common pink* of old gardens, from Europe. Low, growing in mats, glaucous-blue: leaves grass-like: flowers very fragrant, deep-fringed, white or pink. Perennial.

D. Caryophýllus, Linn. *Carnation.* Two ft. or more, with wiry stems, glaucous-blue: leaves grass like: calyx-bracts short and broad: petals more or less toothed but not fringed: flowers fragrant. Europe.

aa. *Flowers in compact clusters.*

D. barbàtus, Linn. *Sweet William.* Fig. 456. One ft. or more, erect, green: flowers small, in dense clusters in red and white. Old World; common in old gardens.

456. Dianthus barbatus.

2. SAPONÀRIA. Soapwort.

Calyx cylindrical or angled, 5-toothed, with no bracts at its base: stamens 10: styles 2: pod 4-toothed at top (Fig. 250).

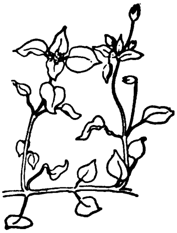
S. officinàlis, Linn. *Bouncing Bet.* Perennial, forming colonies in old yards and along roads, 1–2 ft. high, glabrous, with ovate or oval leaves: flowers 1 in. across, white or rose, in dense clusters, often double, the petals with a crown. Europe. Common.

3. **LȲCHNIS.** Lychnis. Cockle.

Annual or perennial, with styles usually 5, and pod opening by 5 or more teeth: calyx 5-toothed and 10- or more-nerved, naked at the base: stamens 10.

L. Githàgo, Scop. (or *Agrostemma Githago,* Linn.). *Corn cockle,* because it is a common weed in wheat fields (wheat is known as corn in Europe), its seeds not being readily separated from wheat because of their similar size and its seasons corresponding with those of wheat: annual, 2–3 ft., hairy: flowers purple-red and showy, on very long stalks, the petals crowned and the calyx-lobes long and leafy: leaves very narrow. Europe.

L. Coronària, Desv. *Dusty miller. Mullein pink.* Biennial or perennial, white-woolly all over: leaves oblong: flowers rose-crimson, showy, Europe. Old gardens and along roads.


457. Stellaria media.

4. **STELLÀRIA.** Chickweed.

Small, weak herbs with sepals 4–5, petals of equal number and deeply cleft or sometimes wanting: stamens 10 or less: styles usually 3: pod opening by twice as many valves as there are styles.

S. mèdia, Smith. *Common chickweed.* Fig. 457. Little prostrate annual, making a mat in cultivated grounds, with ovate or oblong leaves mostly on hairy petioles: flowers solitary, minute, white, the 2-parted petals shorter than the calyx, the peduncle elongating in fruit. Europe; very common. Blooms in cold weather.

5. **CERÀSTIUM.** Mouse-ear Chickweed.

Differs from Stellaria chiefly in having 5 styles and pod splitting into twice as many valves. The two following gray herbs grow in lawns. From Europe.

C. viscòsum, Linn. Annual, about 6 in. high: leaves ovate to spatulate: flowers small, in close clusters, the petals shorter than the calyx, and the pedicels not longer than the acute sepals.

C. vulgàtum, Linn. Perennial and larger, clammy-hairy: leaves oblong: pedicels longer than the other obtuse sepals, the flowers large.

XI. RANUNCULÀCEÆ. Crowfoot or Buttercup Family.

Mostly herbs, with various habits and foliage: parts of the flower typically all present, free and distinct, but there are some apetalous and diœcious species: stamens many: pistils many or few, in the former case becoming akenes and in the latter usually becoming follicles. Upwards of 30 genera and 1,000 to 1,200 species. Characteristic plants are buttercup, anemone, meadow-rue, marsh-marigold or cowslip, adonis, clematis, larkspur, aconite, columbine, baneberry, peony. Known from Rosaceæ by the hypogynous flowers.

A. Fruits akenes, several or many from each flower.
  B. True petals none, but sepals petal-like (and involucre often simulating a calyx).
    C. Involucre of 2 or more leaves much beneath the flower 1. *Anemone*
    CC. Involucre of 3 sepal-like leaves close to the flower..2. *Hepatica*
  BB. True petals present, yellow..........................3. *Ranunculus*
AA. Fruits follicles.
  B. Petals not spurred, mostly yellow.....................4. *Caltha*
  BB. Petals spurred.......................................5. *Aquilegia*

1. ANEMÒNE. ANEMONY. WIND-FLOWER.

Low perennial herbs with mostly showy apetalous flowers and an involucre of 2 or more mostly divided leaves standing some distance below the flower: pistils ripening into a head of akenes.

a. *Akenes woolly or silky.*

A. Japónica, Sieb & Zucc. *Japanese anemony.* Three ft., blooming in fall, with pink or white flowers 2–3 in. across: leaves with 3 cordate-ovate notched leaflets. Much planted.

A. Virginiàna, Linn. Two ft., with involucre of three 3-parted leaves: flowers on long stalks arising in succession from succeeding nodes: sepals 5, acute, greenish-white: head of fruit oblong, ½ in. long. Woods.

aa. *Akenes not woolly or silky.*

A. quinquefòlia, Linn. (*A. nemorosa* of some). *Common wind-flower.* Low, about 6 in., blooming in rich woods in early spring: involucral leaves 3, each with 3 or 5 long leaflets: flowers white, purplish outside, pretty.

2. HEPÀTICA. LIVERLEAF. MAYFLOWER of some places.

Differs from Anemone chiefly in having 3 simple sepal-like bracts beneath the flower (but they are sometimes a half-inch removed from it): flowers in earliest spring, white, blush or blue, on simple hairy scapes: leaves broad, 3-lobed. Woods.

H. trìloba, Chaix. Leaves with rounded lobes.

H. acutìloba, DC. Leaves with acute lobes.

3. RANÚNCULUS. CROWFOOT. BUTTERCUP. Figs. 2, 187, 188, 191, 242.

Perennials or annuals, with mostly yellow flowers: sepals 5: petals 5, and bearing a little pit or scale at the base inside: leaves alternate: akenes many in a head.

R. àcris, Linn. *Tall buttercup.* Two to 3 ft., from a fibrous root: leaves 3-parted, all the divisions sessile and again 3-cleft: flowers bright yellow. Europe, but now a common weed. Summer.

R. bulbòsus, Linn. Earlier, and only half as tall, from a bulbous base: leaves 3-parted, the lateral divisions sessile and the terminal one stalked: peduncles furrowed: flowers bright yellow. Europe; common eastward.

R. septentrionàlis, Poir. Stems more or less prostrate at base, often forming long runners: leaves 3-divided, divisions all stalked and 3-lobed or -parted: petals obovate, yellow. Wet places.

4. **CÁLTHA.** MARSH MARIGOLD. COWSLIP (in America).

Low tufted herbs with undivided leaves, and clusters of yellow buttercup-like flowers: sepals 5–9, petal-like: petals none: pistils 5–10, ripening into several-seeded follicles.

C. palústris, Linn. About 1 ft. high: leaves rounded or kidney-shaped, crenate or nearly entire. Wet places, in early spring. Used for "greens."

5. **AQUILÈGIA.** COLUMBINE.

Upright herbs, with compound leaves which have petioles expanded at the base: sepals 5, somewhat petal-like: petals 5, each one produced into a long nectary spur; pistils 5: fruit a several-seeded follicle. Delphinium or larkspur is an allied genus.

458.
Aquilegia Canadensis.

a. *Spurs straight.*

A. Canadénsis, Linn. *Common wild columbine.* Often incorrectly called *honeysuckle.* Fig. 458. About 2 ft.: leaflets rounded or obovate, toothed at top: flowers about 2 in. long, drooping, scarlet and orange or nearly yellow, the stamens projecting. Common on rocks.

A. chrysántha, Gray. *Yellow columbine.* Flowers bright yellow, erect or becoming so. New Mexico and Arizona, but frequent in gardens.

aa. *Spurs hooked at the end.*

A. vulgàris, Linn. *Blue columbine.* A European species, common in gardens, and often full double: flowers varying from blue and purple to white, with rather short and thick hooked spurs.

XII. CRUCÍFERÆ. MUSTARD FAMILY.

Herbs, mostly of small stature, with alternate mostly simple leaves: flowers 4-merous as to envelopes, the four petals usually standing 90 degrees apart and thereby forming a cross (whence the name Cruciferæ or "cross-bearing"): stamens usually 6, two of them shorter: fruit a silique or silicle. A very natural or well-marked family, with about 180 genera and nearly 2,000 species. Familiar plants are mustard, shepherd's purse, honesty, cress, pepper-grass, wallflower, stock, cabbage, turnip, radish, horse-radish.

A. Fruit a silique (much longer than broad).
  B. Silique tipped with a long point or beak, extending beyond the valves, the latter often more than 1-nerved .... 1. *Brassica*
  BB. Silique not prominently beaked beyond the valves, each valve strongly 1-nerved .... 2. *Barbarea*

AA. Fruit a silicle (short and broad).
  B. Partition in the pod parallel to the sides.................3. *Alyssum*
  BB. Partition crosswise the pod.
    C. Pod obcordate, many-seeded..........................4. *Capsella*
    CC. Pod orbicular, 2-seeded...............................5. *Lepidium*

1. **BRÁSSICA.** MUSTARD.

Erect branchy herbs, mostly annual, with more or less lyrate lower leaves, and small yellow flowers in racemes or panicles: petals clawed or narrowed below, the limbs spreading horizontally: silique narrow, cylindrical or 4-angled, the valves 1–5-nerved and the seeds in 1 row in each locule. Cabbage, cauliflower, and turnip also belong to this genus. The three following are common weeds introduced from Europe.

B. nìgra, Koch. *Black mustard.* Fig. 459. Leaves pinnatifid, somewhat hairy: pod short, strongly 4-angled, not hairy. Mustard (flour) comes largely from this species.

B. álba, Boiss. *White mustard.* Leaves pinnatifid and rough-hairy: pods rather slender, hairy, but only the lower part seed-bearing.

B. Sinapístrum, Boiss. *Charlock.* Leaves strongly toothed: pod knotty, hairy or smooth, the upper third indehiscent and 2-edged.

459. Brassica nigra.

2. **BARBARÈA.** WINTER CRESS.

Low herbs, blooming in early spring, with many small light yellow flowers, and lyrate leaves with the terminal division much the largest: pod cylindrical or somewhat 4-angled, the valves having a strong midvein: seeds in a single row.

B. vulgàris, R. Br. *Common winter cress. Yellow rocket.* Biennial, about 1 ft. high, with smooth foliage and flowers in elongating clusters: lower leaves lyrate, upper ones cut or merely toothed. Low grounds.

460. Alyssum maritimum.

3. **ALÝSSUM.** ALYSSUM.

Small plants, mostly trailing, with entire and small leaves: pod small, orbicular, one or two seeds in each locule: flowers in elongating racemes.

A. marítimum, Linn. *Sweet alyssum* of the gardens (from Europe). Fig. 460. Annual, producing a profusion of small white, fragrant flowers.

4. **CAPSÉLLA.** SHEPHERD'S PURSE.

Low short-lived annuals, with very small white flowers in racemes: pod obcordate or inversely triangular, the partition running across the narrow diameter, containing several seeds.

C. Búrsa-pastòris, Mœnch. *Common shepherd's purse.* Fig. 259. One of the commonest little weeds: root leaves pinnatifid or strong-toothed, in a rosette, the stem leaves arrow-shaped. Europe.

5. LEPÍDIUM. Pepper Grass.

Small stiffish annuals (or biennials), which shed their leaves late in the season: flowers very small, white or greenish, in elongating racemes: pod small and roundish, the partition running across the narrow diameter. Plant peppery to the taste.

L. Virgínicum, Linn. *Common pepper grass.* About 1 ft. high, much branched, glabrous: leaves linear to lanceolate, tapering to the base, the lower mostly pinnatifid. Common weed; often fed to canary birds.

XIII. MALVÀCEÆ. Mallow Family.

Herbs or shrubs (trees in the topics) with alternate, mostly simple leaves which have stipules: flowers perfect and regular, 5-merous, often subtended by a calyx-like involucre, the petals 5: stamens many, united in a column which closely surrounds the several styles: ovaries several, connivent into a ring or sometimes united into a compound pistil, in fruit making 1-seeded 1-loculed more or less indehiscent carpels or a several-loculed capsule. About 60 genera and 700 species. Representative plants are mallow, hollyhock, abutilon, hibiscus, althea, okra, cotton.

A. Anthers borne only at the top of the stamen-tube.
  B. Fruits 1-seeded, forming a ring at the base of the styles.
    C. Involucre of 3 bracts....................................1. *Malva*
    CC. Involucre of 6–9 bracts................................2. *Althæa*
  BB. Fruit of several-seeded carpels.........................3. *Abutilon*
AA. Anthers borne all along the side of the stamen-tube.........4. *Hibiscus*

1. MÁLVA. Mallow.

Herbs, with a 3-leaved involucre like an extra calyx: petals obcordate: carpels many in a ring, separating at maturity, 1-seeded and indehiscent: leaves usually nearly orbicular in general outline.

M. rotundifòlia, Linn. *Common mallow. Cheeses.* Fig. 224. Trailing biennial or perennial, rooting: leaves orbicular, indistinctly lobed, toothed: flowers small, white or pinkish, clustered in the axils. Yards and roadsides; from Europe. A common weed.

2. ALTHǼA. Marsh Mallow.

Differs from Malva chiefly in having a 6–9-cleft involucre.

A. ròsea, Cav. *Hollyhock.* Figs. 206, 207, 235. Tall perennial, with angled or 5–7-lobed cordate leaves, and large flowers in many colors. China.

3. ABÙTILON. Indian Mallow. Fig. 170.

Mostly shrubs, often with maple-like leaves, and no involucre to the flower: ovaries and fruits several-seeded. Contains conservatory plants.

A. striàtum, Dicks. *Flowering maple.* Fig. 461. Shrub: leaves 3–5-lobed, green: flowers drooping, on long solitary axillary peduncles, bell-shaped, veiny-orange or red. Brazil. A conservatory and house plant.

A. Thómpsoni, Hort. *Spotted flowering maple.* Like the last, but the leaves spotted with yellow, and the column of stamens strongly projecting from the flower. Common in cultivation.

461. Abutilon striatum.

4. **HIBÍSCUS.** Rose Mallow.

Herbs or shrubs, with an involucre of many narrow bracts: stamen-column anther-bearing most of its length: styles 5, united: pod 5-loculed, loculicidal: flowers large and showy.

H. Syrìacus, Linn. *Althea* of cultivated grounds. *Rose of Sharon.* Shrub 10 ft.: leaves wedge-ovate and 3-lobed: flowers showy, in various colors, in the leaf-axils in summer and fall, often double. Asia.

XIV. GERANIÀCEÆ. Geranium Family.

Herbs, chiefly with simple leaves: flowers perfect, in most genera nearly regular (but sometimes very irregular), 5-merous: stamens as many or twice as many as the sepals, hypogynous: ovary single, the locules usually as many as the sepals: fruit capsular. A most diverse family, often divided into several. There are about 20 genera and 700 species. Common examples are geranium, pelargonium, nasturtium, balsam, jewel-weed or touch-me-not, oxalis.

A. Flowers regular or very nearly so.
  B. Leaves simple (often deeply lobed).
    C. Anther-bearing stamens 10........................1. *Geranium*
    CC. Anther-bearing stamens about 7...................2. *Pelargonium*
  BB. Leaves compound....................................3. *Oxalis*
AA. Flowers very irregular.
  B. Flower with one very long spur.......................4. *Tropæolum*
  BB. Flower hanging by its middle, with a short hooked spur.5. *Impatiens*

1. **GERÀNIUM.** Cranesbill.

Small herbs with forking stems and 1–3-flowered peduncles: sepals and petals 5: glands on the torus 5, alternating with the petals: stamens 10, usually all of them with perfect anthers: fruit 5 1-seeded carpels separating from the axis from the base upwards and curling outwards.

G. maculàtum, Linn. *Common wild cranesbill.* Fig. 181. Perennial, 1-2-ft., hairy erect: leaves orbicular, deeply 5–7-parted: petals entire, hairy on the claw: flower rose-purple, 1 in. across. Common; spring.

G. Robertiànum, Linn. *Herb Robert.* Annual or biennial, 1 ft. or sometimes less, somewhat hairy, spreading: leaves 3- or 5-divided into pinnatifid divisions: fls. ½ in. or less across, pink-red. Moist places; common.

2. **PELARGÒNIUM.** Geranium of gardens.

Somewhat fleshy, strong-scented plants, differing from Geranium in having a somewhat 2-lipped corolla, and stamens with anthers less than 10.

P. hortòrum. *Garden geranium. Fish geranium.* Fig. 183. Stem somewhat succulent and hairy: leaves orbicular or reniform, crenate-lobed, often with bands of different colors: flowers in umbel-like clusters, deflexed in bud, of many colors, often double. South Africa, but of hybrid origin.

3. **ÓXALIS.** Oxalis. Wood-sorrel.

Low often tuberous herbs with small flowers which have no glands on the torus-disk: leaves digitate, of 3 or more leaflets, usually mostly radical: flowers (opening in sun) with 5 sepals and petals and 10 somewhat monadelphous stamens, the alternate ones shorter: pod 5-loculed, often opening elastically. The following have 3 obcordate leaflets, closing at night.

O. stricta, Sav. *Common yellow oxalis.* Fig. 273. Stem leafy and branching: peduncles bearing 2–6 small yellow flowers. Common in fields.

O. Acetosélla, Linn. *Wood-sorrel.* Scape 2–5 in. high, from a creeping rootstock: flowers white and pink-veined. Deep woods.

O. violàcea, Linn. Scape 5–10 in. high with an umbel of several bright violet flowers, from a scaly bulb. Woods south, and a common window-garden plant.

4. **TROPÆÒLUM.** Nasturtium of gardens.

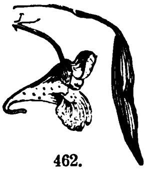
Tender, mostly climbing herbs (by means of leafstalks), with one of the 5 petals extended into a long, nectar-bearing yellow spur: petals usually 5, with narrow claws, often bearded: stamens 8, of different shapes: carpels 3, indehiscent in fruit. The following (from Peru) have peltate orbicular leaves (Fig. 126).

T. màjus, Linn. *Climbing nasturtium.* Tall-climbing: flowers yellow, red, cream-white, and other colors: petals not pointed.

T. minus, Linn. *Dwarf nasturtium.* Fig. 195. Not climbing: petals with a sharp point.

5. **IMPÀTIENS.** Touch-me-not. Jewel-weed

Soft or succulent tender herbs with simple alternate or opposite leaves and very irregular flowers: sepals 3 to 5, usually 4, one of them produced into a large curving spur: petals apparently 2, but each consisting of a united pair: stamens 5: fruit 5-valved, elastically discharging the seeds (whence the names "Impatiens" and "touch-me-not").



462.
Impatiens biflora.

I. Balsámina, Linn. *Garden balsam.* Erect and stout, 1–2½ ft.: leaves lanceolate, toothed: flowers in the axils, of many colors, often full double.

I. biflòra, Walt. (*I. fulva,* Nutt.). *Orange jewel-weed.* Fig. 462. Tall branching plant (2–4 ft.) with alternate oval or long-oval blunt-toothed long-stalked leaves: flowers ¾ in. long, horizontal and hanging, orange-yellow with a red-spotted lower lip, the upper lip less spotted and of one piece, the two green sepals at the apex of the pedicel closely appressed to the tube, the tail of the spur curled under the spur: pod opening elastically when ripe, throwing the seeds (the 5 valves quickly curling from above downwards). Common in swales.

463. Impatiens aurea.

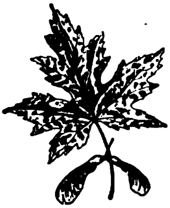
I. aùrea, Muhl. (*I. pallida,* Nutt.). *Yellow jewelweed.* Fig. 463. Leaves usually stronger-toothed, the teeth usually ending in sharp points: flowers 1 in. long and much broader than those of I. biflora, clear yellow, the upper lip of two parts, the lower also of two parts and nearly horizontal, the 2 sepals at apex of pedicel large and not closely appressed, tail shorter: pods as in the other. Less common than the other, but often growing with it.

XV. SAPINDÀCEÆ. SOAPBERRY OR MAPLE FAMILY.

Trees or shrubs, of various habit: flowers polypetalous or apetalous, often inconspicuous, 4- or 5-merous: stamens 10 or less, borne on a fleshy ring or disk surrounding the single 2–3-loculed pistil: fruit a pod or samara. A various family, largely tropical. Genera about 75, and species about 600 to 700. Maple, box-elder, buckeye, horse-chestnut, bladder-nut, are familiar examples.

1. ACER. MAPLE. BOX-ELDER.

Trees or shrubs, with opposite lobed or parted leaves (pinnate in box-elder): flowers small and greenish or reddish, in early spring and often from winter buds, in box-elder diœcious, in true maples perfect (or imperfectly diclinous): calyx about 5-cleft: petals 5 or none: stamens usually 3–8: fruit a samara with 2 seeds and 2 wings. Two shrubby woods maples are common in some parts of the country.

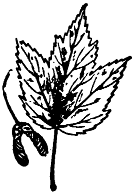


464. Acer saccharinum.

a. *Maples: leaves simple, palmately lobed.*

b. *Flowers from lateral winter buds, preceding the leaves: fruit maturing very early.*

A. saccharinum, Linn. (*A. dasycarpum,* Waugh). *White* or *silver maple.* Fig. 464. Flowers greenish, with no petals: leaves very deeply 5-lobed, silvery white beneath, the narrow divisions lobed and toothed: fruit with large spreading wings, downy when young. Common along streams and in low grounds; much planted. There is a cut-leaved form known as Wier's maple, popular as a lawn tree. Wood white. Linnæus thought it to be the sugar maple, hence his name "saccharinum."



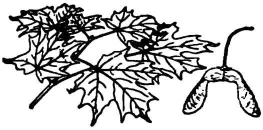
465. Acer rubrum.

A. rùbrum, Linn. *Red, soft,* or *swamp maple.* Fig. 465. Tree usually of only medium size: flowers red, with narrow-oblong petals:

leaves rather small, not deeply 3–5-lobed, whitish beneath, the lobes serrate and toothed: fruit with nearly parallel or slightly spreading wings, not downy. Low grounds.

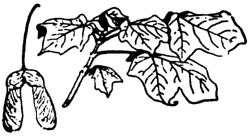
bb. *Flowers in clusters, with the leaves, some or all on shoots of the season.*

A. sácharum, Marsh. (*A. saccharinum* of some). *Sugar, hard,* or *rock maple.* Figs. 129, 466. Flowers greenish, drooping, on long pedicels, the petals none and the calyx hairy at the top: leaves bright green, firm, cordate-orbicular in outline, 3-lobed and the side lobes again lobed, all lobes and teeth ending in points, the basal sinus broad and open: wings of fruit somewhat spreading. Commonest of maples east.



466. Acer saccharum.

A. nigrum, Michx. *Black sugar maple.* Fig. 467. Foliage dark and limp, the lobes broad and shallow, little toothed and with only blunt points, the basal sinus nearly or quite closed: wings of fruit nearly parallel, large. Eastern Central States; by some regarded as a form of *A. saccharum.*



467. Acer nigrum.

A. platanoides, Linn. *Norway maple.* Figs. 75, 76, 77, 144, 296–303. Flowers late, in umbel-like clusters, yellowish green, large, with both sepals and petals: leaves large and heavy, 3–5-lobed and much toothed, all parts ending in points: fruit with wide-spreading wings. Europe. Commonly planted: has milky juice and a round, dense head.

aa. *Box-elder: leaves pinnate.*

A. Negúndo, Linn. (*Negundo aceroides*, Moench). *Box-elder.* Tree with green glaucous twigs and leaf-bases covering the buds: flowers in long racemes, diœcious, with 4–5-cleft calyx and no corolla, and 4–5-stamens, the sterile flowers on long, slender pedicels: leaves pinnate, with 3–5 ovate-pointed toothed leaflets: fruit with somewhat incurving wings. Common: much planted in cold and dry regions west.

XVI. LEGUMINÒSÆ. Pulse or Pea Family.

Herbs, shrubs, or trees, mostly with pinnately compound alternate leaves: flower papilionaceous in the species described below: fruit typically a legume. A vast family and widely dispersed, with many tropical species. Genera about 400, and species about 6,500. By some authors, the species with papilionaceous flowers are separated into the family Papilionaceæ, and those of the acacia tribes, with regular flowers, as the Mimosaceæ. Familiar leguminous plants are pea, bean, lupine, clover, alfalfa, vetch, wistaria, locust, red-bud.

A. Shrub, twining.......................................1. *Wistaria*
AA. Herbs.
B. Plant climbing by tendrils.
C. Calyx leafy lobed.......................................2. *Pisum*
CC. Calyx not leafy lobed ....3. *Lathyrus*
BB. Plant not tendril-bearing.
C. Leaves digitate, of 3 leaflets ....4. *Trifolium*
CC. Leaves pinnate (terminal one-stalked, and the stalk jointed), of 3 leaflets.
D. Flowers small, in very slender racemes............5. *Melilotus*
DD. Flowers small to medium, in heads or short spikes.6. *Medicago*
DDD. Flowers medium to large, clustered at the joints of raceme.
E. Keel of corolla coiled into a spiral..............7. *Phaseolus*
EE. Keel curved but not coiled.....................8. *Vigna*

1. **WISTÀRIA.**

Tall shrubby twiner, producing long, dense racemes of showy flowers: leaves pinnate, with several or many leaflets: 2 upper calyx-teeth shorter: standard large and roundish: pod knotty, several-seeded.

W. Chinénsis, DC. *Wistaria.* Popular climber for porches, from China, with large drooping racemes of bright blue (sometimes white) pea-like flowers in spring and summer.

2. **PÌSUM.** PEA.

Slender herbs, climbing by tendrils which are homologous with leaflets: leaves pinnate, with 1–3 pairs of foliar leaflets, and very large leafy stipules: lobes of calyx leafy: flowers large, white or pink, on axillary peduncles: pod a typical legume, several-seeded.

P. sativum, Linn. *Garden pea.* Figs. 190, 284. Smooth and glaucous: leaflets usually 2 pairs, broad-oval: peduncles 2- or more-flowered. Old World.

3. **LÀTHYRUS.** VETCHLING.

Much like Pisum, differing chiefly in very technical characters, but best told in general by the narrow leaflets and pods, and not leafy calyx.

L. odoràtus, Linn. *Sweet pea.* Figs. 165, 222. Annual, the stem hairy: leaflets one pair, narrow-oval or oblong: flowers 2 or 3 on a long peduncle, very fragrant, in many colors. Southern Europe.

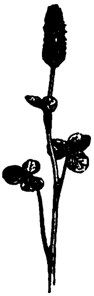
L. latifòlius, Linn. *Everlasting pea.* Fig. 246. Perennial of long duration, smooth, the stems winged: leaflets one pair, long-oval: flowers many in a dense cluster on long peduncles, rose-purple and white. Europe.

4. **TRIFÒLIUM.** CLOVER.

Annual or perennial herbs with digitate leaves of 3 leaflets (all 3 leaflets joined directly to top of petiole): flowers small, with bristle-form calyx-teeth, in dense heads: fruit a 1- to few-seeded little pod which does not exceed the calyx.

a. *Flowers sessile in the dense heads.*

T. praténse, Linn. *Common red clover.* Fig. 82. Erect, 1–2 ft., with oval or obovate leaflets which have a pale spot or band near the center and usually a notch at the end: flowers rose-red, honey-sweet, the heads closely surrounded by leaves. Europe, but common everywhere in the North.


468. Trifolium incarnatum.

T. mèdium, Linn. *Medium red clover.* Larger, the stem less straight, the leaflets oblong, entire and with a spot: head stalked above the uppermost leaves. Otherwise like the last.

aa. *Flowers short-stalked in the heads.*

T. hỳbridum, Linn. *Alsike clover.* Slender, from a prostrate base, 1–3 ft.: leaflets obcordate: head small and globular, light rose-colored. Europe.

T. rèpens, Linn. *White clover.* Small, the stems long-creeping and sending up flowering stems 3–12 in. high: leaflets obcordate: heads small, white. Common; native, also European.

T. incarnàtum, Linn. *Crimson clover.* Fig. 468. Stout, hairy, erect plant, 1–2½ ft., with obovate-oblong leaflets and brilliant crimson flowers in a long stalked head. Europe; now frequently cultivated.

5. **MELILÒTUS.** Sweet Clover.

Tall erect annuals or biennials, with sweet-scented herbage and small white or yellow flowers in numerous open racemes: leaflets 3, oblong: pod ovoid, somewhat exceeding the calyx, 1–2-seeded.

M. álba, Linn. *White sweet clover. Bokhara clover.* Two to 5 ft. tall, smooth: leaflets truncate: flowers white, the standard longer than other petals. Europe; common on roadsides.

M. officinàlis, Linn. *Yellow sweet clover.* Fig. 469. Leaflets obtuse: flowers yellow. Less common than the other.

469. Melilotus alba.

6. **MEDICÀGO.** Medick.

Clover-like plants with small flowers in heads or short spikes and toothed leaflets: particularly distinguished by the curved or coiled pod.

470. Medicago sativa.

M. sativa, Linn. *Alfalfa. Lucerne.* Fig. 470. Erect perennial, with ovate-oblong leaflets and short spikes or dense racemes of blue-purple flowers. Europe, but grown for forage.

M. lupulina, Linn. *Hop clover. Black medick.* Trailing clover-like plant, with obovate leaflets and yellow flowers in heads or very short spikes: pod black when ripe. Europe; common weed East.

7. PHASÈOLUS. Bean.

Tender herbs, often twining, the flowers never yellow, and the pinnate leaves of 3 leaflets: flowers usually in clusters on the joints of the raceme or at the end of the peduncle, the keel (inclosing the essential organs) coiling into a spiral: fruit a true legume.

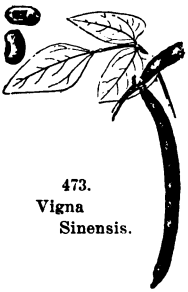
471. Phaseolus vulgaris.

472. Phaseolus lunatus.

P. vulgàris, Linn. *Common bean.* Figs. 282–3, 285–6, 471. Annual: twining (the twining habit bred out in the "bush beans"): leaflets ovate, the lateral ones unequal-sided: flowers white or purplish, the racemes shorter than the leaves: pods narrow and nearly straight. Probably from tropical America.

P. lunàtus, Linn. *Lima bean.* Fig. 472. Annual: tall-twining (also dwarf forms): leaflets large: flowers whitish, in racemes shorter than the leaves: pods flat and curved, with a few large flat seeds. South America.

P. multiflòrus, Willd. *Scarlet runner bean.* Perennial in warm countries from a tuberous root, tall-twining: leaflets ovate: flowers bright scarlet (white in the "Dutch Case-knife bean") and showy, the racemes exceeding the leaves: pod long and broad but not flat. Tropical America; cultivated for ornament and for food.


473. Vigna Sinensis.

8. VÍGNA. Cow-pea.

Differs from Phaseolus chiefly in technical characters, one of which is the curved rather than coiled keel of the flower.

V. Sinénsis, Endl. *Cow-pea. Black pea. Stock pea.* Fig. 473. Long-trailing or twining, tender annual: leaflets narrow-ovate: flowers white or pale, 2 or 3 on the apex of a very long peduncle, the standard rounded: pod slender and long, cylindrical: seed (really a bean rather than pea) small, short-oblong. China, Japan; much grown South for forage.

XVII. ROSÀCEÆ. Rose Family.

Herbs, shrubs and trees, much like the Saxifragaceæ: leaves alternate, mostly with stipules (which are often deciduous): flowers mostly perfect and polypetalous, the stamens usually perigynous: stamens mostly numerous (more than 20): pistils 1 to many: fruit an akene, follicle, berry, drupe, or accessory. A very mixed or polymorphous family, largely of temperate regions, of about 75 genera and 1,200 species. By some writers divided into three or four families.

Common rosaceous plants are rose, strawberry, apple, pear, plum, peach, cherry, blackberry, raspberry, spirea, cinquefoil.

A. Herbs (those described below).
  B. Torus not enlarging: flowers from stems................1. *Potentilla*
  BB. Torus becoming fleshy: flowers directly from the crown or root..2. *Fragaria*
AA. Shrubs or trees.
  B. Ovary 1, free from the calyx and torus, becoming a drupe.3. *Prunus*
  BB. Ovaries many, free from the calyx and torus, becoming drupelets......................................4. *Rubus*
  BBB. Ovaries many, becoming akenes inside a hollow torus....5. *Rosa*
  BBBB. Ovaries 5, immersed in the torus......................6. *Pyrus*

1. POTENTÍLLA. FIVE-FINGER. CINQUEFOIL.

Herbs (sometimes shrubby) with flat deeply 5-cleft calyx and 5 bracts beneath it, and 5 obtuse, mostly yellow or white petals: stamens many: fruit an akene, of which there many in a little head on the small dry torus: leaves compound.

P. Norvégica, Linn. An erect (1–2 ft. tall) very hairy and coarse annual, with 3 obovate or oblong serrate leaflets and small flowers in which the yellow corolla is usually not so large as the calyx. Common weed.

474. Fragaria vesca.

P. Canadénsis, Linn. *Common five-finger.* Trailing, strawberry-like, with 3 narrow leaflets, but the lateral ones deeply lobed: flowers solitary on axillary peduncles, bright yellow. Fields: common.

2. FRAGÀRIA. STRAWBERRY.

Low perennials with 3 broad-toothed leaflets and a few flowers on radical peduncles: torus enlarging in fruit, usually becoming fleshy.

F. vésca, Linn. Fig. 474. Small, very sparsely hairy, the leaves thin and rather light green, very sharply toothed: flower-cluster overtopping the foliage, small and erect, forking: fruit slender and pointed, light colored (sometimes white), the akenes not sunk in the flesh. Cool woods; common North.

475. Fragaria Virginiana.

F. Virginiàna, Duch. *Common field strawberry.* Fig. 475. Stronger, darker green, loose-hairy, the leaves with more sunken veins and larger and firmer: flower-cluster slender but not overtopping the leaves, in fruit with drooping pedicels: fruit globular or broad-conical, with akenes sunk in the flesh, light colored. Very-common.

F. Chiloénsis, Duch. *Garden strawberry.* Fig. 264. Low and spreading but stout, the thick leaves somewhat glossy above and bluish white beneath, rather blunt-toothed: flower-clusters short, forking, the pedicels strong and long: fruit large and firm, dark colored, with sunken akenes. Chile.

476. Prunus Persica.

3. **PRŬNUS.** Peach. Plum. Cherry.

Trees and shrubs, mostly flowering in early spring: sepals, petals and stamens borne on the rim of a saucer-shaped torus, the calyx with 5 green spreading lobes and the petals 5 and obovate: pistil 1, sitting in the bottom of the flower, the ovary ripening into a drupe: leaves alternate.

477. Prunus Armeniaca.

a. *Peach and apricot: flowers solitary from lateral winter buds, usually appearing before the leaves.*

P. Pérsica, Sieb. & Zucc. *Peach.* Fig. 476. Small tree, with oblong-lanceolate pointed serrate leaves and solitary fuzzy fruits on last year's wood. China. The nectarine is a smooth-fruited form.

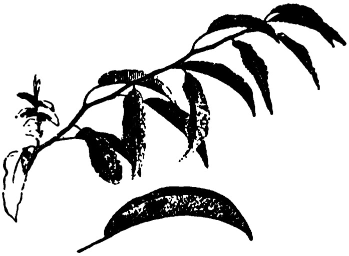
P. Armeniaca, Linn. *Apricot.* Fig. 477. Leaves ovate to round-ovate, serrate: fruits solitary, on last year's shoots or on spurs, smooth or nearly so. China.

aa. *Plums: flowers in umbel-like clusters: fruit large and smooth, usually with a distinct suture (or "crease") on one side and covered with a "bloom," the stalk short.*

P. doméstica, Linn. *Common plum.* Figs. 194, 262. Small tree, usually with young shoots downy: leaves thick and relatively large, dull dark green, ovate, oval or obovate, very rugose or veiny, somewhat pubescent beneath, coarsely and unevenly serrate: flowers large: fruits various, usually thick-meated and with heavy "bloom." Europe, Asia.

P. Americàna, Marsh. *Wild plum* of the North. Fig. 478. Twiggy small tree, often thorny, the young shoots usually not downy: leaves obovate, dull green, abruptly pointed, coarsely toothed or jagged, not pubescent beneath: fruit small, red or yellow, tough-skinned and glaucous, the pit large and flattened. Common in thickets: improved forms are in cultivation.

478. Prunus Americana.


479. Prunus angustifolia.

P. angustifòlia, Marsh. *Chickasaw plum. Mountain cherry.* Fig. 479. Smaller, the young growths smooth and zigzag and usually reddish: leaves lanceolate to oblong-lanceolate, often trough-shaped, shining, finely serrate, cherry-like: fruit a small thin-fleshed shining plum on a long pedicel. Delaware, south; also in cultivation.

480. Prunus Avium.

aaa. *Cherries: flowers in umbel-like clusters: fruit small and nearly globular, early-ripening, usually without a prominent suture and "bloom," the stalk slender.*

P. Cérasus, Linn. *Sour cherry.* Round-headed tree, with flowers in small clusters from lateral buds: leaves hard and stiffish, short-ovate or obovate, grayish green, serrate: fruit small, sour. Europe.

P. Àvium, Linn. *Sweet cherry.* Fig. 480. Straight grower, the "leader" prominent in young trees, with flowers in dense clusters from lateral spurs: leaves oblong-ovate, dull and soft, on the young growths hanging: fruit usually rather large, sweet. Europe.

4. RÙBUS. BRAMBLE.

Shrubs, usually thorny, the canes or shoots dying after fruiting, with alternate digitately compound leaves: flowers white, in clusters, with 5-parted calyx and 5 petals: ovaries many, ripening into coherent drupelets.

a. *Raspberries: drupelets or berry separating from the torus.*

R. occidentàlis, Linn. *Black raspberry.* Figs. 128, 263. Canes long and thorny, glaucous, rooting at the tips late in the season: leaves of mostly 3 ovate doubly-toothed leaflets: flowers in close, umbel-like clusters: fruits, firm, black (sometimes amber-color). Woods, and common in cultivation.

R. strigòsus, Michx. *Red raspberry.* Canes erect and weak-prickly, more or less glaucous, not rooting at tips, leaflets oblong-ovate: flowers in racemes: fruits soft, red. Woods, and cultivated.

aa. *Blackberries: drupelets adhering to the torus (the torus forming the "core" of the berry).*

R. nigrobáccus, Bailey (*R. villosus* of some). *Common blackberry.* Tall, very thorny: leaflets 3 or 5, ovate and pointed, toothed, hairy beneath: flowers large, in open racemes: fruit thimble-shaped and firm, black when ripe. Woods, and cultivated.

R. villòsus, Ait. (*R. Canadensis* of some). *Northern dewberry.* Trailing and rooting at tips, prickly: leaflets 3–7, ovate-acuminate or oblong-ovate, toothed: flowers 1–3, on erect, short peduncles, large: fruit like a small and shining blackberry. Sterile fields, and in cultivation.

R. triviàlis, Michx. *Southern dewberry.* Fig. 158. Long-trailing, very thorny and bristly: leaves 3–5, more or less evergreen, mostly lance-oblong and small, strong-toothed: flowers 1–3: fruit black. Sands, Virginia, south; also in cultivation.

5. **RÒSA.** Rose.

More or less thorny erect or climbing shrubs with pinnate wing-petioled leaves, and flowers with 5 calyx-lobes and 5 large rounded petals: pistils many, becoming more or less hairy akenes which are inclosed in a hollow torus (fruit becoming a hip. Fig. 265). Most of the garden roses are too difficult for the beginner: they are much modified by the plant-breeder.

R. Carolina, Linn. *Swamp rose.* Tall, often as high as a man, the few spines usually nearly or quite straight: stipules (petiole wings) long and narrow: leaflets 5–9, narrow-oblong and acute, finely serrate: flowers rather large, rose-color. Swamps.

R. lùcida, Ehrh. Usually low, with stout hooked spines: stipules rather broad: leaflets about 7, smooth and mostly shining above: flowers large, rose-color. Moist places.

R. hùmilis, Marsh. Three feet or less tall, with straight, slender spines: stipules narrow: foliage usually less shining. Dry soils.

6. **PỲRUS.** Pear. Apple.

Small trees or shrubs with alternate leaves, and flowers in clusters in spring: flowers 5-merous: ovaries usually 5, immersed in the torus, the styles free.

P. commùnis, Linn. *Pear.* Figs. 63, 101, 102, 182, 266. Leaves ovate, firm and shining, smooth, close-toothed: fruit tapering to the pedicel. Europe.

P. Màlus, Linn. *Apple.* Figs. 67, 267, 268. Leaves ovate, soft, hairy beneath, serrate: fruit hollowed at the base when ripe. Europe.

XVIII. SAXIFRAGÀCEÆ. Saxifrage Family.

Herbs or shrubs of various habit, with opposite or alternate leaves that usually do not have stipules: flowers with ovary mostly inferior, 5-merous, the stamens usually 10 or less (in a few cases as many as 40): pistils 10 or less, either separate or the carpels united, the fruit a follicle, capsule, or berry. A polymorphous family comprising some 600 species in about 75 genera. Comprises saxifrage, mitre-wort, hydrangea, mock orange, currant and gooseberry.

A. Leaves opposite..1. *Philadelphus*
AA. Leaves alternate..2. *Ribes*

1. **PHILADÈLPHUS.** Mock Orange (from the flowers). Syringa.

Shrubs with showy corymbose or paniculate white flowers and opposite simple leaves: petals 4 or 5: stamens 20 or more: ovary 3–5-loculed, becoming a capsule.

P. coronàrius, Linn. Tall shrub with erect branches: leaves oblong-ovate and smooth: flowers cream-white, fragrant, in close clusters, in late spring. Europe.

P. grandiflòrus, Willd. Tall, with long recurving branches: leaves ovate-pointed and somewhat downy beneath: flowers pure white, scentless, in loose clusters. Virginia, south, and planted.

2. **RÌBES.** Gooseberry and Currant.

Low shrubs, often prickly, with alternate digitately lobed leaves: flowers small: sepals 5 and petal-like, on the ovary: petals and stamens 5, borne on the calyx: fruit a small globular berry.

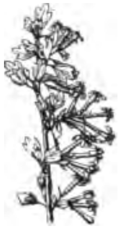
a. *Gooseberries: flowers 1–3: usually spines below the leaves.*

R. oxyacanthoides, Linn. Small bush, with long, graceful branches and very short thorns or none: leaves thin, orbicular-ovate, about 3-lobed, the edges thin and round-toothed: flowers on very short peduncles, the calyx-lobes longer than the calyx-tube, the ovary and berry smooth, the fruit reddish or green. Swamps N.; parent of Houghton and Downing gooseberries.

R. Grossulària, Linn. *English gooseberry.* Stiffer and denser bush, with firm and thickish more shining leaves, which have revolute margins: ovary downy and the large fruit pubescent or bristly. Europe; parent of the large-fruited gooseberries.

481. Ribes rubrum.

482. Ribes Americanum.


483. Ribes aureum.

R. Cynósbati, Linn. Tall, open, prickly bush, with thickish bluntly 3-lobed downy leaves and long peduncles bearing 3 or more flowers with calyx-lobes shorter than the tube: leaves rounded and 3-lobed: fruit dull purple, either prickly or smooth. Common in dry places.

aa. *Currants: flowers in long racemes: no spines.*

R. rùbrum, Linn. *Red and white currant.* Fig. 481. Erect bush, with broad-cordate 3–5-lobed leaves with roundish lobes and not strong-smelling: racemes drooping, the flowers greenish and nearly flat open: berries (currants) red or white. Europe.

R. nigrum, Linn. *Black currant.* Stronger bush, with strong-scented leaves and larger oblong or bell-shaped flowers with bracts much shorter than the pedicels: berries black and strong-smelling. Europe.

R. Americànum, Marsh. (*R. floridum,* L'Her). *Wild black currant.* Fig. 482. Straggling bush, with heart-shaped 3–5-lobed doubly serrate somewhat scented leaves: flowers in long racemes, whitish, with bracts longer than the pedicels: fruit black, scented. Woods.

R. aùreum, Pursh. *Golden, buffalo,* or *flowering currant.* Fig. 483. Large bush, with racemes of long-tubular yellow very fragrant flowers: fruit blackish. Missouri, west, but common in gardens for its flowers.

XIX. UMBELLÍFERÆ. PARSLEY FAMILY.

Herbs, mostly strong-scented and with compound alternate leaves with petioles expanded or sheathing at the base: flowers small, mostly perfect, 5-merous, epigynous, in umbels or umbel-like clusters: stamens 5: fruit consisting of two carpels, which are dry and seed-like and indehiscent. A well-marked natural family of about 1,500 species in about 160 genera. Some of the species are poisonous. Here belong parsley, parsnip, carrot, celery, caraway, sweet cicely. Rather difficult for the beginner.

A. Fruits bristly...1. *Daucus*
AA. Fruits not bristly.
  B. Carpels or "seeds" winged..............................2. *Pastinaca*
  BB. Carpels wingless.
    C. Axis from which the carpels separate not splitting in two...3. *Apium*
    CC. Axis splitting in two when the carpels or "seeds" fall. 4. *Carum*

1. DAÙCUS. CARROT.

Annuals or biennials, bristly, slender and branching, with small white flowers in compound umbels, the rays of which become inflexed in fruit: the fruit oblong, ribbed and bristly.

D. Caròta, Linn. *Carrot.* Fig. 180. Leaves pinnately decompound, the ultimate segments lanceolate: outer flowers with larger petals. Europe; cultivated for the root, and extensively run wild.

2. PASTINÀCA. PARSNIP.

Tall, smooth biennials of strict habit and with pinnately compound leaves: flowers yellow, in compound umbels with scarcely any involucres: fruit oval, very thin, wing-margined.

P. sativa, Linn. *Parsnip.* Flowering stem 2–4 ft. tall, grooved, hollow: leaflets ovate or oblong, sharp-toothed. Europe; cultivated for its roots and also run wild.

3. ÀPIUM. CELERY.

Annuals or biennials, with large pinnate leaves: flowers white, in small umbels: fruit small, usually as broad as long, each carpel 5-ribbed: axis from which the carpels fall not splitting in two.

A. gravèolens, Linn. *Celery*. Biennial, smooth: leaflets 3–7, wedge-shaped or obovate, the lower ones about 3-divided, round-toothed. Europe; cultivated for its petioles, which have become greatly enlarged.

4. CÀRUM. Caraway.

Slender and erect, smooth annual and biennial herbs with pinnate leaves: flowers white or yellowish, in compound umbels provided with involucres: axis bearing the carpels splitting in two at maturity.

C. Cárui, Linn. *Caraway*. Stem furrowed, 1–2 ft.: leaves cut into thread-like divisions: flowers white. Europe. Cultivated for its fruits, known as "Caraway seed," and also run wild.

C. Petroselinum, Benth. *Parsley*. One to 3 ft.: leaflets ovate and 3-cleft, often much cut or "curled" in the garden kinds: flowers yellowish. Europe.

CC. GAMOPETALÆ.

XX. LABIÀTÆ. Mint Family.

Herbs, usually of aromatic scent, with 4-cornered stems and opposite usually simple leaves: flowers typically 2-lipped: stamens 4 in 2 pairs, or only 2: ovary deeply 4-lobed, forming 4 indehiscent nutlets in fruit. A well-marked family of some 2,700 species, distributed in about 150 genera, of both temperate and tropical regions. To this family belong the various mints, as peppermint, spearmint, catnip, hyssop, thyme, pennyroyal, savory, rosemary, sage, horehound, balm, basil. Flowers mostly in whorls in the axils of leaves or bracts, sometimes forming interrupted spikes.

A. Stamens 2.
  B. Calyx about equally toothed, hairy within ....1. *Monarda*
  BB. Calyx 2-lipped, naked within.........................2. *Salvia*
AA. Stamens 4.
  B. Corolla scarcely 2-lipped..............................3. *Mentha*
  BB. Corolla strongly 2-lipped.
    C. Calyx 2-lipped ....4. *Brunella*
    CC. Calyx nearly or quite regular.
      D. Upper or inner pair of stamens longer............5. *Nepeta*
      DD. Lower or outer pair longer.
        E. Tube of corolla including the stamens .... .6. *Marrubium*
        EE. Tube with stamens projecting ....7. *Leonurus*

1. MONÁRDA. Horse-mint.

Rather stout, mostly perennials, with flowers in close terminal heads: calyx tubular, 15-nerved, hairy in the throat, the teeth nearly equal: corolla strongly 2-lipped, the upper lip erect, the lower spreading and 3-lobed.

M. fistulòsa, Linn. Two to 5 ft., in clumps: leaves ovate-lanceolate: flowers in a clover-like flattish head: calyx slightly curved: corolla about 1 in. long, purple. Common in dry places.

2. **SÁLVIA.** Sage.

Annuals or perennials, mostly with large and showy flowers: calyx and corolla 2-lipped: upper lip of corolla large and usually arched, entire or nearly so, the lower lip spreading and 3-lobed: stamens 2, short, the anther locules separated by a transverse bar.

S. officinàlis, Linn. *Common sage.* Erect low perennial, with gray pubescent foliage: leaves oblong-lanceolate, crenulate, very veiny: flowers blue, in spiked whorls. Europe; used for seasoning.

S. spléndens, Sell. (*S. coccinea* of gardens). *Scarlet sage.* Tender perennial from Brazil, but much cultivated for its bright scarlet floral leaves, calyx, and corolla: leaves ovate-pointed.

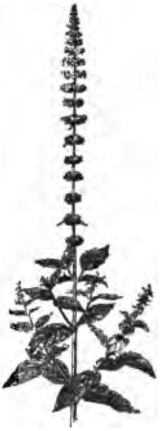
3. **MÉNTHA.** Mint.

Low perennials: calyx with 5 similar teeth: corolla nearly or quite regular, 4-cleft: stamens 4, equal: flowers in heads or interrupted spikes, purplish or white.

M. piperita, Linn. *Peppermint.* Straggling, 1–3 ft. tall, the plant dark colored (stems purplish): leaves ovate-oblong, or narrower, acute, sharply serrate: flowers light purple, in thick spikes 1–3 in. long. Europe. Cultivated and escaped.

M. spicàta, Linn. (*M. viridis,* Linn.). *Spearmint.* Fig. 484. Erect and smooth, 1–2 ft., green: leaves lanceolate and sharply serrate: flowers whitish or tinted, in long, interrupted spikes. Europe. Along roadsides, and cultivated.

M. Canadénsis, Linn. *Wild mint.* One to 2 ft., pubescent: leaves lanceolate: flowers tinted, in whorls in the axils of the leaves. Low grounds.



484.
Mentha spicata.

4. **BRUNÉLLA.** Self-heal.

Low, usually unbranched perennials without aromatic odor: calyx about 10-nerved, 2-lipped: corolla 2-lipped, the upper lip arched and entire, the lower one 3-lobed: stamens 4, in pairs, ascending under the upper lip.

B. vulgàris, Linn. *Self-heal.* Three to 10 in. tall, with ovate or oblong usually slightly toothed leaves: flowers small, violet (rarely white), in a dense, oblong, clover-like head or spike. Common in grassy places.

5. **NÉPETA.** Catmint.

Perennials, mostly sweet-scented: calyx nearly equally 5-toothed: corolla 2-lipped, the upper lip erect and somewhat concave, the lower 3-lobed: stamens 4, in pairs under the upper lip, the outer pair the shorter.

N. Catària, Linn. *Common catmint* or *catnip.* Fig. 197. Erect, 2–3 ft., pubescent: leaves cordate-ovate, crenate, grayish: corolla tinted: flowers in interrupted spikes. Introduced from Europe.

6. **MARRÙBIUM.** HOREHOUND.

Erect perennials, with white-woolly aspect: calyx nearly equally 5–10-toothed, the teeth very sharp: corolla 2-lipped, the upper lip erect and notched, the lower one spreading and 3-lobed: stamens 4, included in the corolla-tube.

M. vulgàre, Linn. *Common horehound.* Leaves broad-ovate and crenate: flowers small, white, in dense whorls. Europe, but common.

7. **LEONÙRUS.** MOTHERWORT.

Erect perennials with green aspect: calyx about equally 5-toothed, the teeth becoming spine-like: corolla 2-lipped, the upper lip somewhat arched and entire, the lower spreading and 3-lobed: stamens 4, ascending under the upper lip: nutlets 3-angled.

L. Cardìaca, Linn. *Common motherwort.* Tall: leaves rounded and lobed: corolla purple, the upper lip bearded: flowers in axillary whorls. Introduced from Europe. Common.

XXI. CONVOLVULÀCEÆ. CONVOLVULUS FAMILY.

Herbs, mostly twining, with alternate chiefly simple leaves: flowers regular, 5-merous, the tubular or trumpet-shaped corolla mostly twisted in the bud, the stamens 5 and borne on the corolla: ovary commonly 1-, mostly 2-loculed, with 2 ovules in each locule, becoming a globular capsule in fruit (which is sometimes 4-loculed by the insertion of a false partition). The family contains between 30 and 40 genera, and nearly 1,000 species. Common convolvulaceous plants are morning-glory, cypress vine, sweet potato, bindweed, dodder.

A. Plants with normal foliage.................................1. *Ipomœa*
AA. Plants leafless, parasitic....................................2. *Cuscuta*

1. **IPOMŒ̀A.** MORNING-GLORY.

Mostly twining, with showy flowers on axillary peduncles: corolla with a long tube and a flaring limb: pistil 1, with one style, and the stigma 2–3-lobed: fruit a capsule, with 1-seeded locules.

a. *Leaves compound, with thread-like divisions.*

I. Quámoclit, Linn. *Cypress vine.* Fig. 485. Leaves pinnate: flowers solitary, red, small, narrow-limbed, with projecting style and stamens. Tropical America, but run wild South; also cultivated. Annual.

aa. *Leaves simple or deeply lobed, broad.*

I. Bòna-Nóx, Linn. *White moonflower.* Fig. 486. Tall: leaves heart-shaped, or angled or lobed: flowers 1 to few,

485. Ipomœa Quamoclit.

white, opening once at night, with a slender tube and a large limb 4–6 in. across. Trop. Amer. Perennial.

486. Ipomœa Bona-Nox.

I. purpùrea, Roth. *Morning-glory.* Fig. 217. Leaves broadly cordate-ovate, entire: flowers 2–4, large and funnel-shaped, 2–3 in. long, purple to streaked and white. Trop. Amer. Annual.

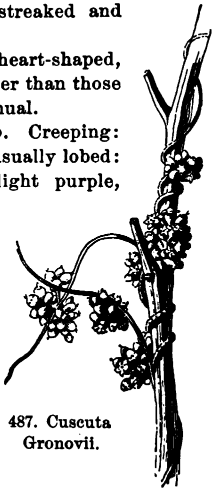
I. hederàcea, Jacq. Leaves heart-shaped, 3–5 lobed: flowers 1–3, rather smaller than those of I. purpurea. Trop. Amer. Annual.

I. Batàtas, Poir. *Sweet potato.* Creeping: leaves heart-shaped to triangular, usually lobed: flowers (seldom seen) 3 or 4, light purple, funnelform, 1½ in. long. Tropics; grown for its large edible root-tubers.

2. **CÙSCUTA.** DODDER.

Parasitic twiners without foliage (leaves reduced to scales): flowers in clusters, the calyx and corolla with 4–5 lobes: fruit 2-loculed, 4-seeded. (See p. 89.)

C. Gronòvii, Willd. (Fig. 487), is the commonest species, twining its slender coral-yellow stems over coarse herbs in swales: corolla bell-shaped, the tube longer than the blunt and spreading lobes.



487. Cuscuta Gronovii.

XXII. SOLANÀCEÆ. NIGHTSHADE FAMILY.

Herbs or shrubs, with alternate often compound leaves: flowers perfect and regular, 5-merous, mostly rotate or open-bell-shaped in form and plaited in the bud: stamens 5, often connivent around the single 2-loculed pistil, borne on the corolla: fruit a berry or capsule (the latter sometimes 4-loculed by a false partition), the seeds borne on a central column. Some 70 genera and 1,500 species. Common representatives are nightshade, potato, tomato, husk tomato, tobacco, jimson-weed, petunia.

A. Fruit a fleshy berry.
  B. Stamens with anthers equaling or exceeding the filaments.
    C. Anthers separate, opening at top..................1. *Solanum*
    CC. Anthers united, opening lengthwise ....2. *Lycopersicum*
  BB. Stamens with anthers much shorter than filaments..3. *Capsicum*
AA. Fruit a capsule.
  B. Calyx 5-parted to near the base.....................4. *Petunia*
  BB. Calyx toothed, not deep-parted.
    C. Pod usually prickly, large.......................5. *Datura*
    CC. Pod not prickly, small..........................6. *Nicotiana*

1. **SOLÀNUM.** Nightshade.

Perennials or annuals : calyx and corolla 5-parted, the latter rotate : stamens 5, exserted, the anthers separate and opening by a pore in the top: berry 2-loculed.

a. *Plants not prickly.*

S. tuberòsum, Linn. *Potato.* Figs. 42, p. 35, 219. Low, diffuse-growing perennial, producing stem-tubers on slender underground rootstocks: leaves pinnate, the leaflets differing in size and ovate: flowers bluish: berries globular, yellowish green. Warm temperate elevations of tropical America.

S. nìgrum, Linn. *Common nightshade.* Branchy annual, 1–2 ft., nearly smooth: leaves ovate, wavy-margined: flowers small, white: berries small, black. Waste places.

S. Dulcamàra, Linn. *Bittersweet.* Tall, loosely climbing: leaves cordate-ovate, sometimes 3-lobed, often with 2 or 4 small leaflets at the base: flowers small, violet-purple: berries oval, red. Perennial. Common.

aa. *Plants prickly.*

S. Melóngena, Linn. *Eggplant. Guinea squash.* Fig. 261. Stout annual with large, ovate, somewhat angled pubescent leaves: flower large, purplish, the calyx prickly: fruit a very large purple or white berry (often weighing several pounds). India.

2. **LYCOPÉRSICUM.** Tomato.

Differs from Solanum chiefly in having the anthers united at their tips by a membrane and opening by lengthwise slits.

488. Capsicum annuum.

L. esculéntum, Mill. *Common tomato.* Fig. 186. Tall, hairy, strong-smelling herb, with pinnate leaves, the leaflets ovate and unequal-sided and of different sizes: flowers small, yellow, in short forked racemes: fruit a large red or yellow berry. South America.

3. **CÁPSICUM.** Red Pepper.

Erect, branchy, smooth herbs: stamens with slender filaments which are much longer than the separate anthers, the latter opening by lengthwise slits : fruit globular, long or irregular, firm.

C. ánnuum, Linn. *Common red pepper.* Fig. 488. Annual or biennial, with ovate entire leaves: flowers white, with very short-toothed or truncate calyx : fruit very various in the cultivated varieties. Trop. Amer.

4. **PETÙNIA.** Petunia.

Clammy-hairy diffuse herbs: calyx-lobes leaf-like and much longer than the tube: corolla funnel-form, showy, the stamens not projecting: fruit 2-loculed, capsular. South America.

P. nyctaginiflòra, Juss. *White petunia.* Fig. 489. Corolla white, very long-tubed : leaves oval-oblong, narrowed into a petiole. Old gardens.

489. Petunia nyctaginiflora.

P. violàcea, Lindl. Fig. 490. Weaker and more diffuse: corolla purple or rose, the tube short and broad: leaves ovate or oval, nearly or quite sessile. The garden petunias are mostly hybrids of the two species.

490. Petunia. Very near the original P. violacea.

5. **DATÙRA.** Jamestown-weed or Jimson-weed.

Very strong bushy herbs, with large, long-tubular, short-lived flowers from the forks of the branches: stigma 2-parted: fruit a globular usually prickly capsule, opening by 4 valves.

D. Stramònium, Linn. Fig. 248. Annual, 3–5 ft., the stem green: leaves ovate, sinuate or angled: corolla white. Tropics; common weed.

491. Nicotiana alata.

D. Tàtula, Linn. Stem and corolla purple.

6. **NICOTIÀNA.** Tobacco.

Tall herbs, with large usually pubescent leaves: corolla funnelform or salverform, the tube usually long: stigma not lobed: pod 2–4-valved, not very large, contained within the persistent calyx.

N. Tabàcum, Linn. *Tobacco.* Robust annual, 4–6 ft., with very large ovate decurrent entire leaves and rose-purple panicled flowers. Trop. Amer.

N. alàta, Link & Otto (*N. affinis* of gardens). Fig. 491. Slender but tall (2–4 ft.) plant with clammy-pubescent herbage: leaves lanceolate or obovate, entire: flowers white, with very slender tube 5–6 in. long, the limb unequal. Brazil; common in gardens.

XXIII. SCROPHULARIÀCEÆ. Figwort Family.

Herbs (trees in warm countries), of various habit: flowers perfect, irregular, usually imperfectly 5-merous: corolla usually 2-lipped and personate: stamens 4 in 2 pairs, inserted on the corolla, with sometimes a rudiment of a fifth: ovary single, 2-loculed, ripening into a several- or many-seeded capsule. About 160 genera and 2,000 species. Representative plants are figwort, snapdragon, toad-flax, foxglove, mullein, pentstemon, monkey-flower or musk-plant.

A. Corolla shallow and nearly regular......................1. *Verbascum*
AA. Corolla very irregular, often personate.
  B. Flower with a long spur............ ....2. *Linaria*
  BB. Flower spurless.
    D. Blossoms erect, swollen at the base ....3. *Antirrhinum*
    DD. Blossoms drooping, not swollen, with narrow limb..4. *Digitalis*
    DDD. Blossoms not drooping, with 2-lipped limb ....5. *Mimulus*

1. **VERBÁSCUM.** Mullein.

Tall biennials, with alternate decurrent leaves: calyx and corolla 5-parted, the latter shallow and nearly or quite rotate: stamens 5, some or all of the filaments woolly.

V. Tháspus, Linn. *Common mullein.* Figs. 22, 133. Two to 5 ft., stout and usually unbranched, white-woolly: leaves oblong and acute, felt-like: flowers yellow, in a very dense spike. Weed from Europe.

V. Blattària, Linn. *Moth mullein.* Slender and branching, green and nearly smooth: leaves oblong, serrate, often laterally lobed, somewhat clasping: flowers yellow or cream-colored, in a loose raceme. Weed from Europe.

492. Linaria vulgaris.

2. **LINÀRIA.** Toad-flax.

Low herbs, of various habit: corolla personate, the throat nearly or entirely closed, spurred from the lower side: stamens 4: capsule opening by apical pores.

L. vulgàris, Mill. *Toad-flax. Butter-and-eggs.* Figs. 255, 492. Common perennial weed (from Europe), 1–2 ft., with linear leaves and yellow flowers in racemes.

L. Cymbalària, Mill. *Kenilworth ivy.* Fig. 493. Trailing: leaves orbicular, 5–7-lobed: flowers solitary on long peduncles, lilac-blue. Europe; very common in greenhouses and sometimes runs wild.

493. Linaria Cymbalaria.

3. **ANTIRRHÌNUM.** Snapdragon.

From Linaria differs chiefly in having no spur, but only a swelling at the base of the corolla.

A. màjus, Linn. *Snapdragon.* Fig. 220. Erect biennial or perennial: leaves oblong, smooth, entire: flowers erect or ascending, 2 in. long, purple or white, in a raceme with downy axis. Europe.

4. **DIGITÀLIS.** Foxglove.

Stem simple and strict: leaves alternate: flowers with a long expanding tube and a very short indistinctly lobed limb, the throat wholly open: stamens 4.

D. purpùrea, Linn. *Common foxglove.* Usually biennial, tall and stout (2–4 ft.): leaves oblong, nearly or quite entire, rough and downy: flowers many, drooping in a long, erect raceme, 2 in. long, white to purple and spotted inside. Old garden plant from Europe.

494. Mimulus luteus.

5. **MÍMULUS.** Monkey-flower.

Small herbs with opposite leaves, with usually showy solitary flowers on axillary peduncles: calyx 5-angled and 5-toothed: corolla tubular, the 2-lobed upper lip erect or spreading: stamens 4: stigma 2-lobed.

M. ríngens, Linn. *Wild monkey-flower.* Erect perennial, with square stem and oblong or lanceolate clasping serrate leaves: flowers blue or light purple, somewhat personate. Wet places.

M. lùteus, Linn. *Monkey-flower. Tiger-flower.* Fig. 494. Annual, with ovate serrate leaves: flowers large, yellow, blotched with brick-red or brown. Western America, and commonly cultivated. To gardeners often known as *M. tigridioides.*

XXIV. CAPRIFOLIÀCEÆ. Honeysuckle Family.

Erect or twining shrubs, or sometimes herbs, with opposite mostly simple leaves: flowers epigynous, 5-merous, regular or irregular, tubular or rotate: stamens usually as many as the lobes of the corolla and inserted on its tube: ovary 2-5-loculed, ripening into a berry, drupe, or capsule. About 15 genera and 200 species. Characteristic plants are honeysuckle, elder, viburnum, snowberry, weigela, twin-flower.

A. Corolla long-tubular..1. *Lonicera*
AA. Corolla shallow, usually rotate.
  B. Leaves simple..2. *Viburnum*
  BB. Leaves pinnately compound............................3. *Sambucus*

1. **LONÍCERA.** Honeysuckle.

Erect or twining shrubs, with tubular, funnelform, more or less irregular flowers (often 2-lipped): corolla bulging on one side near the base: stamens 5: fruit a berry, usually 2 together from 2 contiguous flowers.

a. *Erect.*

L. ciliàta, Muhl. Open, smooth bush, 3–5 ft.: leaves cordate-oblong, not sharp-pointed, entire: flowers less than 1 in. long, soft yellow, the lobes nearly equal: berries red. Common in woods. Blooms in very early spring.

495. Lonicera Japonica.

L. Tatárica, Linn. *Tartarian honeysuckle.* Fig. 85. Tall shrub (to 12 ft.): leaves cordate-oval, not long-pointed, entire: flowers pink or red (sometimes nearly white), 2-lipped, all the lobes oblong. Asia, but common in yards. Spring.

aa. *Twining.*

L. Japónica, Thunb. (*L. Halliana* of gardens). Fig. 495. Weak twiner, with oblong or ovate entire nearly evergreen leaves: flowers small, on short pedicels, fragrant, opening white or blush but changing to yellow. Japan; much cultivated.

L. Periclýmenum, Linn. Probably the commonest of the old-fashioned climbing honeysuckles (from Old World): strong and woody: leaves oblong-ovate, not joined by their bases, entire, dark green above and pale beneath: flowers large, reddish outside and yellow inside, very fragrant, in a dense, long-stalked cluster.

2. **VIBÚRNUM.** ARROWWOOD.

Erect shrubs, with simple leaves and small whitish flowers in broad cymes: stamens 5: stigmas 1–3: fruit a small 1-seeded drupe

a. *Flowers all alike in the cyme.*

V. Lentàgo, Linn. *Black haw. Sheepberry.* Fig. 279. Tall shrub (to 20 ft.): leaves ovate-pointed, finely and sharply serrate, shining above, on long margined petioles: fruit ½ in. or more long, black. Common.

V. acerfòlium, Linn. *Dockmackie. Arrowwood.* Six ft. or less: leaves 3-lobed and maple-like, downy beneath: cyme small and slender-stalked: fruit flat and small. Woods.

aa. *Flowers larger on the margin of the cyme.*

V. Ópulus, Linn. *High-bush cranberry.* Erect, 10 ft. or less: leaves 3-lobed and toothed: outer flowers sterile and large: fruit an acid red edible drupe. Swamps. In cultivation all the flowers have become sterile, resulting in the "snowball." Compare Figs. 236, 237.

V. tomentòsum, Thunb. (*V. plicatum* of gardens). *Japanese snowball.* Leaves not lobed, shallow-toothed, thickish, plicate: heads of sterile flowers axillary, globular. Japan.

3. **SAMBÚCUS.** ELDER.

Strong shrubs, with pinnate leaves and sharp-serrate leaflets: flowers in dense corymbose cymes: calyx-teeth very small or none: corolla shallow, open: stamens 5: stigmas 3: pith prominent in the stems. Common.

S. racemòsa, Linn. *Red elder.* Pith and berries red: flowers in spring in pyramidal clusters: leaflets lanceolate, downy beneath.

S. Canadénsis, Linn. *Common elder. White elder.* Pith white: berries black-purple, in late summer, edible: flower-clusters convex or nearly flat, in summer: leaflets oblong, smooth.

XXV. COMPÓSITÆ. COMPOSITE OR SUNFLOWER FAMILY.

Mostly herbs, many of them very large, very various in foliage: flowers small, densely packed into an involucrate head, 5-merous, the corolla of the outer ones often developed into long rays: stamens

5, the anthers united around the 2 styles: fruit dry and 1-seeded, indehiscent, usually crowned with a pappus which represents a calyx. The largest of all phenogamous families, comprising about one-tenth of all flowering plants,—about 800 genera and 11,000 to 12,000 species. Common composites are sunflower, aster, goldenrod, boneset, dahlia, chrysanthemum, marigold, compass plant, thistles, dandelion, lettuce.

- A. Head with all the flowers strap-shaped (with rays) and perfect: juice milky: leaves alternate.
  - B. Flowers yellow........ 1. *Taraxacum*
  - BB. Flowers blue or pink........ 2. *Cichorium*
- AA. Head with tubular and mostly perfect disk flowers, the rays, if any, formed of the outer strap-shaped and imperfect flowers. In cultivated species, all the flowers may become strap-shaped (head "double"): juice not milky.
  - B. Fruit a completely closed and bur-like involucre, containing one or two small akenes: flowers imperfect.
    - C. Involucre-bur large and sharp-spiny........ 3. *Xanthium*
    - CC. Involucre-bur small, not sharp-spiny........ 4. *Ambrosia*
  - BB. Fruit not formed of a closed and hardened involucre (although the involucre may be spiny, as in Arctium and Cnicus).
    - C. Pappus none.
      - D. Leaves opposite, simple........ 5. *Ageratum*
      - DD. Leaves alternate.
        - E. Foliage finely divided........ 6. *Achillea*
        - EE. Foliage entire, toothed or broad-lobed.
          - F. Akenes curved or horseshoe-shaped........ 7. *Calendula*
          - FF. Akenes straight.
            - G. Torus flat or slightly convex........ 8. *Chrysanthemum*
            - GG. Torus conical........ 9. *Rudbeckia*
    - CC. Pappus of 2 thin early deciduous scales........ 10. *Helianthus*
    - CCC. Pappus a short crown........ 11. *Tanacetum*
    - CCCC. Pappus of many bristles.
      - D. Plant very prickly........ 12. *Cnicus*
      - DD. Plant not prickly.
        - E. Involucre prickly and bur-like........ 13. *Arctium*
        - EE. Involucre not a bur nor prickly.
          - F. Torus bristly (chaff or bracts amongst the florets)........ 14. *Centaurea*
          - FF. Torus naked.
            - G. Rays present.
              - H. Color yellow, the heads very small........ 15. *Solidago*
              - HH. Color not yellow.
                - I. Scales of involucre unequal........ 16. *Aster*
                - II. Scales equal in length........ 17. *Erigeron*
                - III. Scales in several rows, more or less leafy........ 18. *Callistephus*
            - GG. Rays none........ 19. *Eupatorium*

1. **TARÁXACUM.** DANDELION.

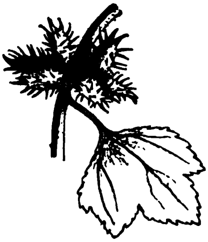
Stemless herbs, the 1-headed scape short, leafless and hollow: florets all perfect and strap-shaped: fruit ribbed, the pappus raised on a long beak.

T. officinàle, Weber (*T. Dens-leonis*, Desf.). *Common dandelion.* Figs. 8, 275. Perennial, introduced from the Old World: leaves long, pinnate or lyrate: heads yellow, opening in sun.

2. **CICHÒRIUM.** CHICORY.

Tall, branching perennials, with deep, hard roots: florets perfect and strap-shaped: fruit lightly grooved, with sessile pappus of many small, chaffy scales.

C. Íntybus, Linn. *Common chicory*, run wild along roadsides (from Europe): 2–3 ft.: leaves oblong or lanceolate, the lowest pinnatifid: flowers bright blue or pink, 2–3 together in the axils on long nearly naked branches.

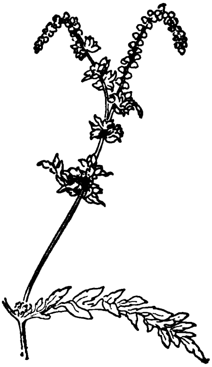


496. Xanthium Canadense.

3. **XÁNTHIUM.** CLOTBUR.

Coarse homely annual weeds with large alternate leaves, flowers monœcious: in small involucres: sterile involucres composed of separate scales, in short racemes: fertile involucres of united scales forming a closed body, clustered in the leaf axils, becoming spiny burs.

X. Canadénse, Mill. *Common clotbur.* Fig. 496. One to 2 ft., branching: leaves broad-ovate, petioled, lobed and toothed: burs oblong-conical, 1 in. long, with 2 beaks. Waste places.



497. Ambrosia artemisiæfolia.

X. spinòsum, Linn. *Spiny clotbur.* Pubescent, with three spines at the base of each leaf: bur ⅛ in. long. with 1 beak. Tropical America.

4. **AMBRÒSIA.** RAGWEED.

Homely strong-smelling weeds, monœcious: sterile involucres in racemes on the ends of the branches, the scales united into a cup: fertile involucres clustered in the axils of leaves or bracts, containing 1 pistil, with 4–8 horns or projections near the top. Following are annuals:

A. artemisiæfòlia, Linn. *Common ragweed.* Fig. 497. One to 3 ft., very branchy: leaves opposite or alternate, thin, once- or twice-pinnatifid: fruit or bur globular, with 6 spines. Roadsides and waste places.

A. trífida, Linn. *Great ragweed.* Three to 12 ft., with opposite 3-lobed serrate leaves: fruit or bur obovate, with 5 or 6 tubercles. Swales.

5. **AGERÀTUM.** AGERATUM.

Small diffuse mostly hairy herbs, with opposite simple leaves: heads small, blue, white or rose, rayless, the involucre cup-shaped and composed of narrow bracts: torus flattish: pappus of a few rough bristles.

A. conyzoides, Linn. (*A. Mexicanum* of gardens). Annual pubescent herb, with ovate-deltoid serrate leaves: cultivated (from tropical America) for its small and numerous clustered soft heads.

6. **ACHILLÈA.** YARROW.

Low perennial herbs: heads small, corymbose, many-flowered, white or rose, with fertile rays: scales of involucre overlapping (imbricated): torus flattish, chaffy: pappus none.

A. Millefòlium, Linn. *Yarrow.* Stems simple below, but branching at the top into a large rather dense umbel-like flower cluster: leaves very dark green, twice-pinnatifid into very fine divisions: rays 4–5. Fields everywhere.

7. **CALÈNDULA.** POT MARIGOLD.

Erect, quick-growing annuals, with terminal large yellow or orange heads with pistillate rays: involucre of many short green scales: torus flat: pappus none: akenes of the ray florets (those of the disk florets do not mature) curved or coiled.

C. officinàlis, Linn. *Common pot marigold.* A common garden annual from the Old World, with alternate entire sessile oblong leaves: 1–2 ft.

8. **CHRYSÁNTHEMUM.** CHRYSANTHEMUM.

Erect herbs, annual or perennial, with alternate lobed or divided leaves: rays numerous, pistillate and ripening seeds: torus usually naked, flat or convex: pappus none.

a. *Akenes of ray florets winged.*

C. morifòlium, Ram. (*C. Sinense*, Sabine). *Greenhouse chrysanthemum.* Tall and mostly strict, with lobed, firm and long-petioled alternate leaves: flowers exceedingly various. China.

aa. *Akenes not winged.*

C. Leucánthemum, Linn. *Whiteweed. Ox-eye daisy.* Fig. 169. Perennial, with many simple stems from each root, rising 1–2 ft., and bearing alternate oblong sessile pinnatifid leaves: heads terminating the stems, with long white rays and yellow disks. Fields everywhere in the East, and spreading West.

9. **RUDBÉCKIA.** CONE-FLOWER.

Perennial or biennial herbs, with alternate leaves and showy yellow-rayed terminal heads: ray florets neutral: scales of involucre in about 2 rows, leafy and spreading: torus long or conical, with a bract behind each floret: akenes 3-angled, with no prominent pappus.

R. hírta, Linn. *Brown-eyed Susan. Ox-eye daisy* in the East. Fig. 498. Biennial, 1–2 ft., coarse-hairy, leaves oblong or oblanceolate, nearly entire, 3-nerved: rays as long as the involucre or longer, yellow, the disk brown: torus conical. Dry fields.

R. laciniàta, Linn. Two to 7 ft., perennial, smooth, branching: leaves pinnate, with 5–7-lobed leaflets, or the upper ones 3–5-parted: rays 1–2 in. long: torus becoming columnar. Low places.

498. Rudbeckia hirta.

10. **HELIÁNTHUS.** Sunflower.

Stout, often coarse perennials or annuals, with simple alternate or opposite leaves and large yellow-rayed heads: ray florets neutral: scales of involucre overlapping, more or less leafy: torus flat or convex, with a bract embracing each floret · akene 4-angled: pappus of two scales (sometimes 2 other smaller ones), which fall as soon as the fruit is ripe.

a. *Disk brown.*

H. ánnuus, Linn. *Common sunflower.* Tall, rough, stout annual, with mostly alternate stalked ovate-toothed large leaves: scales of involucre ovate-acuminate, ciliate. Minnesota to Texas and west, but everywhere in gardens.

H. rígidus, Desf. *Prairie sunflower.* Stout perennial (2–6 ft.), rough: leaves oblong-lanceolate, entire or serrate, rough and grayish, thick and rigid: heads nearly solitary, with 20–25 rays. Prairies, Michigan, west.

aa. *Disk yellow (anthers sometimes dark).*

H. gigantèus, Linn. Tall, to 10 ft., rough or hairy: leaves mostly alternate, lanceolate-pointed, finely serrate or quite entire, nearly sessile: scales linear-lanceolate, hairy: rays pale yellow, 15–20. Low grounds.

H. divaricàtus, Linn. Figs 3, 4, 23, 27. Small for the genus, 1–4 ft.: leaves opposite, ovate-lanceolate, 3-nerved, sessile, serrate, rough and thickish: rays 8–12, 1 in. long. Common in dry thickets.

H. tuberòsus, Linn. *Jerusalem artichoke.* Bearing edible stem-tubers below ground: 5–10 ft.: leaves ovate to oblong-ovate, toothed, long-petioled: scales not exceeding the disk: rays 12–20, large. Penn. west, and cultivated.

11. **TANACÈTUM.** Tansy.

Tufted perennials, with finely divided leaves and strong odor: involucre of overlapping dry scales: torus convex: heads small, nearly or quite rayless, the flowers all seed-bearing: akenes angled or ribbed, bearing a short crown-like pappus.

T. vulgàre, Linn. *Common tansy* from Europe, but run wild about old houses: 2–4 ft.: leaves 1–3-pinnately cut: heads yellow, pappus-crown 5-lobed.

12. **CNÌCUS.** Thistle.

Perennial or biennial herbs, with pinnatifid, very prickly leaves: florets all tubular and usually all perfect: scales of the involucre prickly: torus bristly: pappus of soft bristles, by means of which the fruit is carried in the wind.

C. lanceolàtus, Hoffm. *Common thistle.* Figs. 228–230, 276. Strong, branching biennial: leaves pinnatifid, decurrent, woolly beneath: heads large, purple, with all the involucre-scales prickly. Europe.

C. arvénsis, Hoffm. *Canada thistle.* Lower, perennial and a pestiferous weed: leaves smooth or nearly so beneath: flowers rose-purple, in small, imperfectly diœcious heads, only the outer scales prickly. Europe.

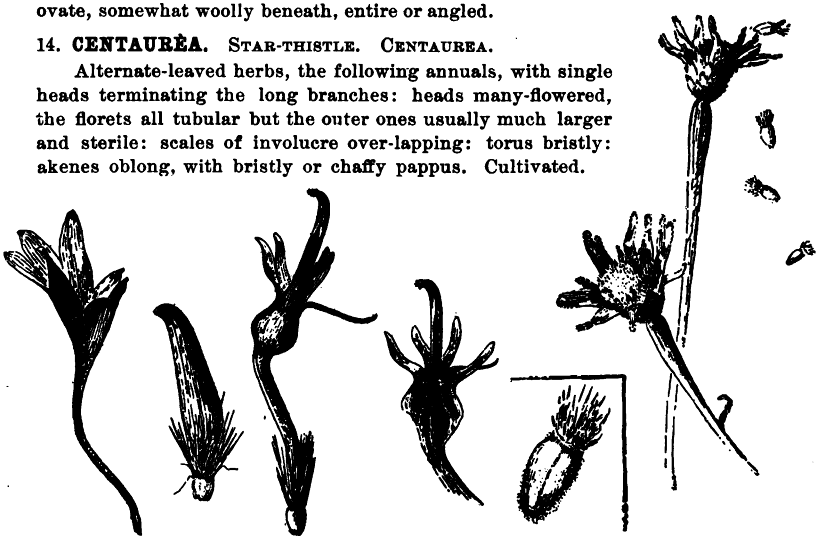
13. **ÁRCTIUM.** Burdock.

Coarse biennials or perennials, strong-scented, with large dock-like simple leaves: head becoming a bur with hooked bristles, the florets all tubular and perfect: torus bristly: pappus of short, rough, deciduous bristles.

A. Láppa, Linn. *Common burdock.* Fig. 280. Common weed from Europe, with a deep, hard root and bushy top 2–3 ft. high: leaves broad-ovate, somewhat woolly beneath, entire or angled.

14. CENTAURÈA. Star-thistle. Centaurea.

Alternate-leaved herbs, the following annuals, with single heads terminating the long branches: heads many-flowered, the florets all tubular but the outer ones usually much larger and sterile: scales of involucre over-lapping: torus bristly: akenes oblong, with bristly or chaffy pappus. Cultivated.



499. Centaurea Cyanus. At the left is an outer or ray floret; then follow three details of a disk floret; then follows the fruit.

C. Cỳanus, Linn. *Corn-flower. Bachelor's button.* Figs. 231, 499. Gray herb: leaves linear and mostly entire: heads blue, rose or white. Europe.

C. moschàta, Linn. *Sweet sultan.* One–2 ft., smooth: leaves pinnatifid: pappus sometimes wanting: heads fragrant, white, rose or yellow, large. Asia.

15. SOLIDÀGO. Goldenrod.

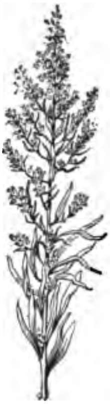
Perennial herbs, with narrow, sessile leaves: heads yellow, rarely whitish, few-flowered, usually numerous in the cluster, the ray-florets 1–16 and pistillate: scales of involucre close, usually not green and leaf-like: torus not chaffy: akene nearly cylindrical, ribbed, with pappus of many soft bristles. Of goldenrods there are many species. They are characteristic plants of the American autumn. They are too critical for the beginner.

16. ÁSTER. Aster. Fig. 227.

Perennial herbs, with narrow or broad leaves: heads with several to many white, blue or purple rays in a single series, the ray florets fertile: scales of involucre overlapping, usually more or less green and leafy: torus flat: akenes flattened, bearing soft, bristly pappus. Asters are conspicuous plants in the autumn flora of this country. The kinds are numerous, and it is difficult to draw specific lines. The beginner will find them too critical.

17. **ERÍGERON.** Fleabane.

Annual, biennial or perennial erect herbs, with simple, sessile leaves: heads few- to many-flowered: rays numerous in several rows and pistillate: scales of involucre narrow and equal, scarcely overlapping, not green-tipped: torus flat or convex, naked: pappus of soft bristles.



500. Erigeron Canadensis.

a. *Rays very inconspicuous.*

E. Canadénsis, Linn. *Horse-weed. Mare's-tail.* Fig. 500. Tall, erect, weedy, hairy annual, with strong scent: leaves linear and mostly entire or the root-leaves lobed: heads small and very numerous in a long panicle, the rays very short.

aa. *Rays prominent: common fleabanes.*

E. ánnuus, Pers. Usually annual, 3–5 ft., with spreading hairs: leaves coarsely and sharply toothed, the lowest ovate and tapering into a margined petiole: rays numerous, white or tinged with purple, not twice the length of the involucre.

E. strigòsus, Muhl. Usually annual, with oppressed hairs or none: leaves usually entire and narrower: rays white and numerous, twice the length of the involucre.

18. **CALLÍSTEPHUS.** China Aster.

Erect, leafy annuals, with large solitary heads bearing numerous white, rose or purple rays: scales in several rows or series, usually leafy: torus flat or nearly so, naked: pappus of long and very short bristles.

C. horténsis, Cass. *Common China aster,* now one of the commonest of garden annuals, in many forms: leaves sessile and coarsely toothed. China.

19. **EUPATÒRIUM.** Boneset.

Erect perennials, with simple leaves: heads small and rayless, clustered, all the florets perfect: scales not leafy: torus flat or low-conical, naked: akene 5-angled: pappus a single row of soft bristles. Low grounds.

E. purpùreum, Linn. *Joe Pye weed.* Tall, with purplish stem and lanceolate toothed leaves in whorls of 3–6: heads flesh-colored, in dense corymbs. Swamps, growing 3–10 ft.

E. perfoliàtum, Linn. *Boneset. Thoroughwort.* Fig. 159. Two to 4 ft., hairy: leaves opposite and sessile, lanceolate, flowers white, in clusters.

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Columella, 181.
Column: body formed of union of stamens and pistil in orchids, (279).
Companion cells, 254.
Compass plant, 50, 269.
Complete flower: all parts present, (257).
Complete leaf: having blade, petiole, stipules, (194), Fig. 131.
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Compound leaves, 91.
Compound pistil: of more than one carpel united, (255).
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Convallaria majalis, 294.
Convolvulaceæ, 328.
Copper sulfate, 241.
Coral root, 85, Fig. 119.
Cork elm, 303, Fig. 450.
Corm: a solid bulb-like part, (81).
Cormel: a corm arising from a mother corm, (81).
Corn, ash in, 72; cells, 237; field, 213, 217, Fig. 358; germination, 168, Figs. 291–295; monœcious, 133, Fig. 214; North and South, 203; phyllotaxy, 49; root cap, 253, Fig. 395; roots of, 8, 12, Fig. 14; water in, 72; wilting, 83; roots, 267; stalk, 18; starch, 248, 249; stems, 259; suffocated, 70; sugar, 246.
Corn cockle, 308.
Cornflower flowers, 143, Figs. 231, 499.
Corolla: inner circle of floral envelopes, (250).
Cortex, 260.
Corymb: short and broad more or less flat-topped indeterminate cluster, (241).
Corymbose inflorescence: outer flowers opening first; indeterminate, (236).
Cotton, 146; fibers, 233.
Cotyledon: seed-leaf (305).
Cowslip, 310.
Cow-pea, 319, Fig. 473.
Cranberry, high-bush, 334.
Cranesbill, wild, 313, Fig. 181.
Creeper: a trailing shoot which takes root throughout its length, (56), 15.
Crenate: shallowly round-toothed, (200).
Cress fruit, 152; winter, 311.
Crocus, 34, 35, Figs. 48, 49, 297, Fig. 438.
Cross-fertilization: secured by pollen from another flower, (260).
Cross-pollination: transfer of pollen from flower to flower, (263).
Crowfoot, 309, Figs. 2, 187, 188, 191, 242.
Crown: that part of the stem at the surface of the ground, (37); tuber, 33.
Cruciferæ, 310; hairs, 270.
Cryptogam: flowerless plant, as fern, moss, fungus, 178, 284, (325).
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Cutting: severed piece of a plant designed to propagate the plant, (51), (61).
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Cymose inflorescence: central flowers opening first: determinate, (243).
Cypress vine, 328, Fig. 485.
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Daucus Carota, 325, Fig. 180.
Daughter cell, 238.
Day-lily, 293. Fig. 253, 433; Fig. 432.
Deciduous: falling (204).
Decompound, 91.
Decumbent, 15.
Decurrent: running down the stem, (195), Fig. 133.
Dehiscence: opening of seed-pod or anther, (264), (287).
Deliquescent: trunk or leader lost in the branches, (40).
Dentaria pod, 147, Fig. 240.
Dentate: sharp-toothed, (200).
Dependent plants, 85.
Dermatogen, 253.
Desert vegetation, Fig. 344.
Determinate: definite cessation of growth at the apex, (243).
Dew, 83.
Dewberry, 21, Fig. 29, 158; fruit, 153.
Dextrose, 245, (231).
Diadelphous; in two groups, (277).
Dianthus, 307, Fig. 456.
Dicentra inflorescence, Fig. 172.
Dichogamy: stamens and pistils maturing at different times, (265).
Diclinous: imperfect; having either stamens or pistils, (257).
Digestion: changing of starchy materials into soluble and transportable forms, (168).
Digitalis purpurea, 332.
Digitate, 91.
Diœcious: staminate and pistillate flowers on different plants, 133.
Dispersal of seeds, 158.
Divergence of character, 213.
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Dog's-tooth violet, 292, Fig. 431.
Dogwood bracts, 106; tree, Fig. 356.
Doorweed, 306, Fig. 193.
Dormant buds, 54.
Double flowers, 144.
Dragon-root, 290.
Dragon's head inflorescence, Fig. 175.
Drupe: fleshy 1-seeded indehiscent fruit; stone fruit, (295).
Drupelet: one drupe in a fruit made up of aggregate drupes, (296).
Dryopteris, 172, 286, Figs. 304, 305, 420.
Ducts, 233, 257.
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Elodea, 78, 235, Fig. 387.
Embryo: the plantlet in the seed, (305).
Embryology, 102.
Embryo-sac, 175.
Emersed, 198.
Emetin, 246.
Endodermis, 253.
Endogenous stems, 259.
Endosperm: food in the seed outside the embryo, (306).
Entire: margin not indented, (200).
Entomophilous: pollinated by insects, (266).
Envelopes, floral, 122.
Environment: surroundings; conditions in which organisms grow 203, (326).
Eosin for staining, 70.
Epicotyl: that part of the caulicle lying above the cotyledons, (312).
Epidermis, 254, 259, 260; of leaf, 270.
Epigeal: cotyledons rising into the air in germination, (311).
Epigynous: borne on the ovary, (283).
Epiphyte, 88, 200.
Equisetum, 192, Fig. 342.
Erigeron, 340, Fig. 500,
Erythronium, 292,Fig. 431.
Esquimaux, 204.
Essential organs: stamens and pistils, (250).
Ether, 241.
Eupatorium, 90, 340, Fig. 159.
Euphorbia pulcherrima, 247.
Eutropic; in the direction of the sun's course, (231).

Evergreen: remaining green, (204).
Everlasting pea, 317, Fig. 246.
Evolution, 232.
Excretion by roots, 71.
Excurrent: the trunk or leader continued through the top, (39).
Exogenous stems, 260.
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Fibrous root, 7; tissue, 255.
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Filament: stalk part of the stamen, (254).
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Five-finger, 320.
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Fleur-de-lis, 297.
Flora: plant population of a country or place; also a book describing this population, (327).
Floral envelopes, 122.
Florets: individual flowers of composites and grasses, 146, (281).
Flower, parts of, 122; -branches, 114; -bud, 39; -cluster, 114; -stem, 119.
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Follicle: dry dehiscent pericarp opening on the front suture, (289).
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Framework, 2, 62, 100, Figs. 3, 4.
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Freesia refracta, 298, Fig. 439.
Fringed wintergreen, 134.
Frog spittle, 178.
Frond: leaf of fern, (317).
Fruit-bud, 39; -dot, 172; sugar, 245.
Fruits, 147.
Fuchsia, 18; and light, 42; bracts, 106, Fig. 160; cuttings, 26; flower, 123, Fig. 189; inflorescence, 115: phyllotaxy, 49; water pores, 271.
Function: what a plant or a part does; its vital activities.
Fundamental tissue, 257.
Fungi, 85, 176, 180.
Funiculus, 164.
Funkia, 293, Figs. 432, 433.
Galanthus nivalis, 296, Fig. 436.
Galium, climbing, 108.
Gametophyte, 174, 194.
Gamopetalous: corolla of one piece, (251).
Gamosepalous: calyx of one piece, (251).
Gemmæ, 187.
Genealogy, 16, 106.
Generation: period from birth to death, (8).
Geranium, 18; chlorophyll, 75; cuttings, 24, 26, Figs. 32, 36, 37; family, 313; fish, 314; inflorescence, Figs. 181, 183; and light, 42; kinds of, 313; in window, 121, 163.
Germination, 164, 165.
Ginger, 19.
Glabrous: not hairy.
Gladiolus, 34, 35, 298, Figs. 50, 440.
Glaucous: covered with a "bloom" or a whitish substance.
Globoid inclusions, 249.
Glomerule: dense head-like cyme, (244).
Gloxinia, leaf cuttings, 22.
Glucose, 245, 247.
Glume, 146.
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Graft: a branch or bud made to grow on another plant, 27, (60), Figs. 31, 39–41.
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Grape crystals, 250; cuttings, 24, 27; fruit, 153; leaves of, 95; sugar, 245; tendrils, 110, 113, Figs. 164, 168.
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Greenbriar tendril, 111; tissue, 259.
Grevillea in window, 163.
Guard cells, 271, Figs. 413, 414.
Guinea squash, 330, Fig. 261.
Gum-resin, 246, 247.
Gymnosperm: seed naked (not in an ovary); applied to pines, spruces, etc., (299), 155, 286.
Habit: the looks, appearance, general style of growth, (36).
Habitat: particular place in which a plant grows, (327).
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Heliotropism: turning towards the light, (100).
Hemerocallis flava, 293; fulva, 293.
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Henna root, 241.
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Hickory, 39, 51, 147, Figs. 59, 60, 83; inflorescence, 117, 133.
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Hip: fruit of the rose, 155, Fig. 265.
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Hollyhock, 312, Figs. 206, 207, 235; flower, 130, 139, Figs. 206, 207, 235; hairs, 235.
Holly, phyllotaxy, 49; tree, Fig. 352.
Homology: related in origin or structure, (211).
Honesty fruit, 152.
Honey locust buds, 37; leaves, 95; thorns, 105; tree, 63.
Honeysuckle buds, 37, 53, Fig. 85; family, 333; leaves, Fig. 134; phyllotaxy, 49; Tartarian, 333, Fig. 85; twiner, 112.
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Horse-chestnut bud, 36; fruit, Fig. 251; leaf-scar, 37; thyrse, Fig. 184.
Horse mint, 326.
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Horse-weed, 340, Fig. 500.
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Hydrangea, 119; doubling, 145.
Hydrogen, 72.
Hydrophytic society, 219, Figs. 369, 377.
Hypocotyl: that part of the caulicle lying below the cotyledons, (311).
Hypogeal: cotyledons remaining beneath the ground in germination, (311).
Hypogynous: borne on the torus, or under the ovary, (283).
Imbedding, 243.
Immersed, 198.
Impatiens, 314, 315, Fig. 462, 463; collenchyma, 254; root-pressure, 73; water pores, 271; seeds, 158.
Imperfect flower: having either stamens or pistils, (257).
Inclusions, 249.
Incomplete flower: any parts wanting, (257).
Indehiscent: not opening, (287).
Independent plants, 85.
Indeterminate: growing on from the apex, (236).
Indian pipe, 85.
Indian turnip, 141, 290, Fig. 226.

India-rubber plant, 246, 250, 251,269.
India wheat, 305.
Indusium, 173.
Inflorescence: mode of flower-bearing: less properly, a flower-cluster, (246).
Insects and flowers, 131.
Internode: space between two joints or nodes, (64).
Inulin, 246.
Involucre: a whorl of small leaves or bracts standing close underneath a flower or flower-cluster, (278)
Iodine test for starch, 31, 249.
Ipecac, 246.
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Karyokinesis: indirect division or transformation of the nucleus, being one means of cell multiplication; mitosis, 239, (393).
Kentucky coffee tree, 96.
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Layer: a branch which takes root and gives rise to an independent plant, (55).
Leaf, fall of, 97; how to tell, 98.
Leaflet: one part in a compound leaf, (192).
Leaf-scars, 37, 273.
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Legume: simple pericarp dehiscing on both sutures, (290).
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Leonurus Cardiaca, 328.
Lepidium Virginicum, 312.
Lettuce, experiment with, 78; wild, 50, 356.
Leucolum vernum, 296.
Levulose, 245.
Lichen, 88, 176, 186.
Life-history: sum of the events in the life of a plant, (7).
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Ligneous: woody, (11).
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Lilac bushes, 100; bud, 41; inflorescence, 119; phyllotaxy, 49.
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Living matter, making of, 74.
Lobed, 92.
Locule: compartment of a pistil, (285).
Loculicidal: dehiscence between the partitions, (292).
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Node: a joint; the space between two joints is an internode.
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Perfect flower: having both stamens and pistils, (257).

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Pericarp: ripened ovary, (286).
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Perigynous: borne around the ovary, (283).
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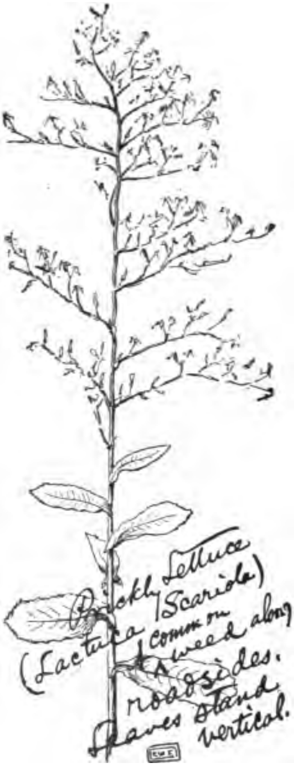
The enlarging ring of a plant which propagates itself by means of rootstocks.—Sacaline, a plant recently introduced from Asia; allied to docks and smartweeds.


Prickly Lettuce
(Lactuca Scariola)
A common weed along roadsides.
Leaves stand vertical.

(See page 50.)

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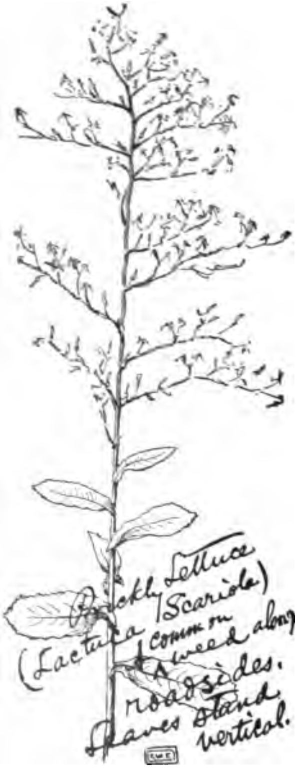
Prickly Lettuce
(Lactuca Scariola)
A common weed along roadsides.
Leaves stand vertical.
EWE

(See page 50.)

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